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Chimpanzees, humans and parasites : sympatry in southeastern Senegal

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Chimpanzees, humans and parasites:
sympatry in southeastern Senegal

by

Michaela Emily Howells

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

Major: Anthropology

Program of Study Committee:
Jill D. Pruetz, Major Professor
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Iowa State University
Ames, Iowa
2006

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Graduate College
Iowa State University

This is to certify that the master's thesis of

Michaela Emily Howells

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

For my parents

Who taught me that even
moths have feelings

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Abstract

The ever increasing geographic overlap between human and nonhuman primates has important ecological, evolutionary and conservation implications. Intensification of contact between chimpanzees (*Pan troglodytes verus*) and burgeoning human populations in southeastern Senegal is resulting in an escalated risk of disease transmission. Our ability to mitigate these potentially deadly results depends on a clear understanding of both population's health and behavior. This study, conducted May-August 2005, addresses the overlap and potential risks of disease transmission of the Fongoli community of chimpanzees and three sympatric human communities. More than 50 interviews with permanent residents in this area suggest that although they do not eat chimpanzees, their lack of sanitary waste management and consumption of water contaminated with coliform places both populations at risk of pathogen transmission. Representative biological samples of both populations were collected and analyzed using non-invasive fecal flotation and sedimentation techniques. Prevalence of helminthes, nematodes, cestodes, and trematodes were compared. Results suggest that there may be some disease transmission between the Fongoli community of chimpanzees and the human communities they are associated with, however it is not possible at this time to determine directionality of transmission. Cultural and biological implications of this study for the long term management of threatened primate populations are discussed. This study addresses the need for baseline data regarding primate health while determining current and potential risks to this vulnerable population.

Chapter One

Introduction

1.1 Human - Nonhuman Primate Commensalisms

The geographic overlap between human and nonhuman primates (NHP) is increasing and has important environmental and ecological implications for conservation of the latter (Fuentes and Wolfe, 2002). Nonhuman primates are predominantly found in areas with extensive human overlap, resulting in a range of threats to their health and wellbeing. According to Conservation International, one-third of the 625 species and subspecies of primates are at risk of extinction (Mittermeier et al., 2000; Konstant et al., 2002). This threat is multiplied as human manipulation of land increases and nonhuman primates are confined into densely populated pockets of remaining habitat (Chapman, 2001). Population compression and the associated increase in interactions among individual and groups results in an escalating risk of disease transmission (Wallis and Lee, 1999).

Combined, the bush meat trade, deforestation and zoonotic disease transmission limit the range of primates, endanger their lives and can lead to dramatic population crashes (Ashford et al., 1996; Le Guenno et al., 1995; Ashford et al., 1996; Wolfe et al., 1998; Wallis and Lee, 1999; Altizer et al., 2003; Lilly, 2002). Scientists from the disciplines of biology, forestry, ecology, environmental biology, population biology, veterinary science, epidemiology and zoology have made vast efforts to curb these destructive practices and their effects on nonhuman animals. Those conservation projects that have been most successful have treated humans not as an annoyance, or noise in the system, but as vital members of a complex ecosystem whose voices are vital to these efforts (Savage et al., 2004).

In southeastern Senegal, the Fongoli community of chimpanzees has lived sympatrically with humans for decades if not millennia. However, increased movement into rural areas by humans may result in increased exposure of this community of chimpanzees to anthropogenic pressures. In association with the Great Ape Health Monitoring Unit (GAHMU; see section 1.6) and the villages of Fongoli, Petit Oubadji and Djendji this study addresses zoonotic parasitic transmission between a community of West African savanna-dwelling chimpanzees (*Pan troglodytes verus*) and three sympatric human communities in southeastern Senegal.

Increasingly, anthropogenic pressures on already endangered primate populations elevate the risk of habitat loss, disease transmission and extinction. Although all primates sharing the human ecological landscapes may be threatened, the shared biology and physiology of chimpanzees (*Pan troglodytes*) and humans place the former at intensified risk. By increasing our knowledge of human and chimpanzee dynamics in this critical area we are able to fundamentally contribute to a greater understanding of great ape health while building a baseline for future research.

1.2 Why Study Human - Chimpanzees Disease Transmission?

Physiological similarities between humans and the non-human great apes have been established through molecular analysis and comparative morphology (Pilbeam, 1996). Chimpanzees in particular have been singled out as the closest living relatives of humans, and these species are estimated to have split from their last common ancestor five to eight million years ago (Pilbeam, 1996). Chimpanzees are the most prolific species of living apes and are known for their psychological and physiological similarities to humans (Goodall, 1986; Pilbeam, 1996). It is for these reasons that chimpanzees are often used as “Flagship

Species” for conservation initiatives and held as extant models of human evolution (Potts, 1987; Hunt, 1994; Moore, 1996; Pontzer and Wrangham, 2003).

In addition to sharing broadly similar genetic and physiological characteristics, chimpanzees share a susceptibility to many of the same infections (Ott-Joslin, 1993; Wolfe et al., 1998). Bacterial, mycobacterial, spirochetal, fungal, parasitic, protozoan and viral infections can all be transmitted between human and nonhuman primates through physical contact, airborne transmission, ingestion, and arthropod vectors (Wallis and Lee, 1999). Deforestation, burgeoning human populations, the removal and butchering of bushmeat, and commensal relationships can lead to exposure of potentially fatal zoonotic diseases in both species (Wolfe et al., 2005). Zoonotic disease transmission between humans and NHPs is frequently more hazardous than transmission from NHP to humans (Brack, 1987).

Devastating emerging infectious agents such as Human Immunodeficiency Virus (HIV), Ebola fever, hantavirus, and dengue have been linked to increased human encroachment on tropical forest communities and their NHP inhabitants (Leroy et al., 2004; Gao et al., 1999; Wolfe et al., 1998). Anthropogenic impact on chimpanzee populations in Gabon, for example, has resulted in dire outcomes for both species. The disastrous decline of great ape populations due to exposure to zoonotic diseases highlights the need for baseline health information in order to effectively track and understand hazardous interactions prior to outbreaks (Wolfe et al., 1998; Landsound-Soukata et al., 1995; Goodall, 1986;).

1.3 The Approach

Baseline Construction of Health

This study initiates a baseline of chimpanzee health for the Fongoli community of chimpanzees in southeastern Senegal. West African chimpanzees (*Pan troglodytes verus* and

P.t. vellerosus) are among the most threatened populations of chimpanzees in the world (Butynski, 2003). Their dwindling numbers in West Africa create an increased urgency for information on how best to conserve the remaining population. In this study, using noninvasive biological sampling techniques, feces were collected from the Fongoli community of chimpanzees and the three human communities utilizing their home range. Presence and absence of endoparasites were determined. Combined with interviews of inhabitants of the local villages regarding public health risks and opinions, these data were used to construct a baseline of health for both species and develop a plan of action sensitive to both humans and chimpanzees.

Previous research has been heavily focused on a responsive approach to disease ecology in primate communities (Ashford et al., 1996; Wallis and Lee, 1999). For example, no baseline of health was developed previous to the catastrophic disease outbreaks in Gabon and the Gombe Stream Reserve, Tanzania (see Chapter 3). This oversight prevents future scientists from developing long-term conservation strategies based on information on pre-outbreak health. Baseline health information on both local fauna and humans in areas of high and low anthropomorphic disturbance would have helped evaluate the pathogenic risks presented to nonhuman primates (Lilly et al., 2002). It becomes clear that the development of such a baseline is important to the maintenance and development of compromised great ape populations (McGrew et al., 1989).

Although it is useful to collect information on the baseline health of communities characterized by low anthropogenic disturbance (Lilly et al., 2002), encroachment on non-human primate populations by humans is increasing. Currently, 90% of the world's primates live outside of protected areas and reserves (Rose and Ammann, 1997). Thus, baseline

information on these unprotected populations is critical to conservation efforts. In instances of anthropogenic disturbance it is also necessary to monitor the health of local human populations while increasing behavioral and ethnographic insight into these groups.

1.4 Hypotheses

The relationship between humans and their environment is a complicated one that encompasses many social, religious, spiritual, medicinal and economic avenues (Fuentes and Wolfe, 2002). A serious consideration of the impact of humans on primate environments, ecology and health is necessary for any primatologist working in close proximity to humans. It is for these reasons that biological anthropologist studying our closest relatives should consider local human populations as important sources of insight into primate behavior and welfare. This study combines ethnographic and non-invasive primatological sampling techniques in order to gain a greater understanding of the interaction between humans and chimpanzees in southeastern Senegal. Of particular interest to this study is zoonotic disease transmission, the bidirectional transmission of diseases between human and nonhuman animals.

This research is important anthropologically in that it enables researchers to address disease transmission between humans and chimpanzees in a non-clinical context (McGrew et al., 1989). Intensified contact between apes and burgeoning human populations has resulted in an escalated risk of disease transmission and associated impacts on the long-term viability of chimpanzee populations in Senegal and beyond. This threat multiplies as human manipulation of land increases and NHPs are confined to densely populated pockets of remaining suitable habitat. This density-dependent relationship is central to epidemiological models of infection risk and pathogen spread.

Thus the objectives of this study were to

1. *investigate the presence or absence of endoparasites in fresh chimpanzee and human fecal material*
2. *establish possible routes of zoonotic endoparasitic transmission between human and chimpanzee populations*
3. *determine if chimpanzees and humans living in sympatric association manifest similar endoparasitic presence and absence*
4. *determine if villages with more sanitary toileting facilities have a lower parasitic diversity than villages with no toileting facilities*

1.5 Conservation Implications

Ignoring the physical health of chimpanzees can impede all other conservation efforts crucial to the survival of these apes. A longitudinal database that includes all available information in regards to great ape health can underscore other conservation efforts and provide a measure of community risk. The recently established Great Ape Health Monitoring Unit (GAHMU) is building a pan-African database that will include health information on chimpanzee and gorilla populations. The purpose of this database is to combine the expertise of veterinarians, ecologists, anthropologists, biologists and other specialists to create a multidisciplinary approach to great ape health that can ultimately contribute to species survival (see Stuart and Strier, 1995). Results from the current project have been submitted to GAHMU in hopes of improving conservation strategies for these threatened animals.

Increasing our understanding of human influence on chimpanzees' health can provide the tools necessary to explore more effective routes of conservation and management that include assistance and support by local human populations. In order to fully assess the interplay between nonhuman primates and their environments, human behavior must be considered an important socioecological variable. This project takes a multifaceted approach

to these complex issues by utilizing primatological, parasitological and ethnographic methodologies.

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Chapter Two

Evolutionary and Behavioral Implications of Parasites

“Now...you see, it takes all the running you can do to keep in the same place” (Carroll, 1872 [1998]).

2.1 Introduction

Although a great deal of attention has been focused on non-human primate utilization of macro environments, a dearth of information remains in regards to the consequences of parasitic infection on primates. The potential impact of parasites on NHP populations cannot be overstated. In addition to an obvious impact on the health of humans and NHP populations, parasitism and parasite avoidance has resulted in behavioral modifications within these species. For instance, coevolution between parasites and their hosts has been proposed as a key factor in mammalian evolution and in the development of sexual reproduction. This chapter discusses the implication of host-parasite interplay in regards to these topics.

2.2 Characterizing Parasites

Parasitic organisms outnumber other nonparasitic organisms in terms of number of taxa and affect nearly all multi-cellular species. They are ubiquitously distributed, inhabit almost every available environment and are representative of a liberal spectrum of biodiversity (Moore, 2002). It is surprising, therefore, that organisms with such an extensive distribution are frequently overlooked in discussions of behavioral ecology and mammalian life history and are disproportionately understudied compared to their hosts (Lewis et al., 2002).

Considerable debate exists regarding the proper definition of parasites (Brooks and McLennan, 1993; Moore, 2002). For this review, parasites are broadly defined as any

infectious organism capable of colonizing a host, utilizing host resources, and spreading to new hosts (Altizer et al., 2003). Parasites are usually subdivided into two categories, microparasites and macroparasites (Roberts and Janovy, 2000). Microparasites include viruses, bacteria, fungi, and protozoa, and are characterized by their small size, short generation times, high rates of reproduction within their host, and short duration of infection, all of which usually results in the host's lifelong immunity, chronic infestation, or death (Anderson and May, 1979; Möller et al., 1993). In contrast, macroparasites include helminthes and arthropods, which have longer generation times and usually complete some aspect of their life history outside of their host(s) (Möller et al., 1993; Hart, 1994). For macroparasitic infections, the host's immune response generally depends on the number of macroparasites it is harboring. However, the relatively short period of infection by the macroparasite usually makes the host susceptible to continuous and multiple reinfections (Möller et al., 1993).

Table 2.1 Life Cycle and Transmission Categories of Parasites

Type of Life Cycle (Direct vs. Indirect)	Method of Acquiring a Host (Active, Passive, Use of Vector)
Direct Life Cycle	Passive Transmission
Direct Life Cycle	Active Transmission
Indirect Life Cycle	Passive Transmission
Indirect Life Cycle	Active Transmission
Indirect Life Cycle	Use of Vectors

Moore (2002) discusses five general types of parasites as defined by their life cycles and the mode of transmission they employ in order to acquire a host (see Table 2.1). These include parasites with either direct or indirect life cycles that are passively or actively transmitted and may depend on disease vectors for transmission. Parasites with direct life

cycles spend the majority of their existence within their hosts. After being ingested these parasites develop, reproduce and are subsequently excreted from the host's body in feces. Examples include human roundworms (*Ascaris lumbricoides*), giardia (*Giardia* spp.), and several species of nematodes (Moore, 2002). In contrast, species with indirect life cycles spend only a portion of their existence within an intermediate host (such as early development), and mature sexually in a separate definitive host.

Understanding whether a host's parasite acquisition is active or passive is as important to parasitic classification as the determination of life cycles (Moore, 2002). In active transmission the parasite seeks out a specific host, utilizing a range of behavioral and chemical methods. These include increasing the probability of host contact by ascending vegetation, seeking warm foot paths, swimming, walking, crawling, and flying, in addition to responding to chemical cues from within their environment (Moore, 2002).

Alternatively, parasites that depend on passive transmission rely on their intermediate hosts to make contact with definitive hosts. This can occur through several behaviors, such as the ingestion of the intermediate host by the definitive host. After the intermediate host ingests the parasite, the parasite can develop into a sexually mature adult and begin the cycle again. Members of the phylum Acanthocephala (thorny headed worms) and some species of tapeworms are examples of macroparasites that utilize this strategy (Moore, 2002).

Also important in the construction of classificatory systems is the use of vectors in transmission. Vectors are vehicles of parasitic transmission and can be biotic (intermediate hosts, ticks, mites, or biting flies) or abiotic (wind, water, dust particles) (Roberts and Janovy, 2000). Many macroparasitic vectors (e.g., tsetse flies, mosquitoes, ticks, mites) can

harbor microparasites (Lyme disease, malaria, Dengue fever, and West Nile virus), which infects their definitive hosts.

2.3 Behavioral Impacts of Parasites on Potential Hosts

Parasites may play a role analogous to that of predatory and abiotic environmental forces in determining and limiting an animal's resources required for growth, development, reproduction, and survival (Anderson and May, 1979). Indeed, parasites resemble predators in that they exact their benefit at the expense of the host or prey. However, because parasites do not typically kill their prey the host-parasite, the predator-prey analogy is weakened (Feldhamer et al., 2004).

Parasite-host interactions are not equivalent to predator-prey relationships because the majority of parasite species depend on their hosts for shelter, sustenance, reproduction, and dispersal (Moore and Clayton, 1997). To this end, it is exceedingly important to minimize the damage a parasite inflicts on its host. Although some parasites frequently kill their hosts, this strategy is maladaptive for some parasitic organisms because it rids itself of a dependable nutritious food supply, its shelter, and its means of dispersal. Since all animals (parasitized or not) must harness food from their environment, complications associated with obtaining foods should be reduced to ensure a healthy host and a plentiful, resource-rich environment for the parasite (Moore, 2002).

Parasites subsisting on animal tissues for continued existence should reduce the "pathologies" or "side effects" they impact on their hosts (May and Anderson, 1990). This strategy ensures that the host can acquire the energetic needs from its environment for both organisms' survival in an efficient manner. Furthermore, by reducing pathologies, the host (e.g., the parasite's environment) should live longer. In theory, increased host longevity and

adequate health should provide the parasite with a reliable environment, allowing the parasite to fully develop, sexually mature, and distribute its offspring (via eggs) throughout the host's home range. Thus, an adaptive strategy for many parasites should focus on minimizing the adverse effects that they incur on their hosts (Allison, 1982).

2.4 Coevolution of Parasites and Other Animals

The role of natural selection in shaping behavioral patterns of animals is a theme woven nearly universally throughout studies of animal behavior (Hart, 1988). The impact of parasites on free ranging primate populations is more difficult to measure than other, more obvious pressures such as deforestation (Gillespie, pers. comm.). Recent studies suggest, however, that beyond their impact on hosts' health, parasites may have played a role in shaping the genetic trajectory of natural selection in host populations. In natural environments the threat of parasitism is unending and is probably responsible for shaping the behavioral, morphological, and physiological adaptations of primates and other multicellular beings (Hart, 1992). Thus, the impact of parasites on human and NHP existence extend far beyond somatic concerns for the individual and may function as important evolutionary pressures.

Conventional wisdom regarding parasite-host interactions asserts that parasites should minimize the negative impacts that they exact on their host (May and Anderson, 1990). Negative impacts include energy allocation, alteration of behavior, sickness, pathologies, and death. Thus, parasites and hosts should co-evolve and ultimately attain an equilibrium that benefits each organism in both a proximate and evolutionary sense. This relationship is characterized by a host, which provides a parasite with shelter from ecological insults, an environment for growth and sexual development, and a method of dispersing offspring. In

turn, parasites should minimize their negative impacts and perhaps provide benefits for their host (e.g., aid in digestion or provide inoculations against similar foreign organisms) (May and Anderson, 1990).

Evolutionary theory maintains that hosts and parasites should behave in ways that increases their reproductive success. Hosts and parasites do co-evolve and co-speciate, but this does not necessitate that relationships result in a perfect “middle ground,” in which the parasite and the host are both in complete biological harmony (Moore and Clayton, 1997). Natural selection has no direction, so it is faulty to suggest that parasites and humans are evolving toward commensal association, for example (May and Anderson, 1990). Instead, this relationship is dependent on a multitude of coevolutionary trajectories that depend on the details of each species’ behaviors and life-history (May and Anderson, 1990; Moore and Clayton, 1997). In this case coevolution is synonymous with diffuse coevolution, where selection pressures due to one species can change in the presence of the other species (Inouyue, 2001).

2.5 Parasite Mediated Selection

Allison (1982) notes that several researchers have rejected the assertion that parasites evolve to be “harmless” to their hosts. If one assumes that parasitic organisms are ancient and ubiquitous, they undoubtedly act as a strong and constant selective evolutionary force. Moreover, it is probable that the magnitude of this force outweighs the selective forces of predation. The fact that parasites inflict pathologies, sicknesses, deaths, and epidemics suggests that parasites actively regulate host population sizes (Anderson and May, 1979), demographic organizations (Freeland, 1976), and genetic variation within a species (Goater and Holmes, 1987).

Evidence of directional evolution triggered by parasitic influence is found in the perpetuation of sickle cell anemia among individuals of African origin (Allison, 1982). This condition is marked by deformed or “sickle” shaped blood cells. Individuals who are homozygous for this trait suffer from sickle cell anemia, a fatal disorder that leads to a blocking of blood vessels due to the irregular shape of their blood cells (Ingram, 1956). However, those who are heterozygous for this trait produce both regular and sickle shaped blood cells and will not develop sickle cell anemia. Although sickle cell anemia is fatal in its homozygous form, heterozygous carriers are at an advantage when exposed to malaria (*Plasmodium falciparum*; Aidoo et al., 2002). In areas where malaria take a massive toll on human life, over 25% of the population of West Africa exhibit these traits (Moatti, 2001). Therefore, the perpetuation of the sickle cell trait is not simply maladaptive but provides those heterozygous for the trait an advantage in regions with high malarial infections.

Evidence of parasitic infections influencing the heritability of resistance of nonhuman animals has been determined through controlled experiments (Sitepu and Dobson, 1982). An example of parasite-driven selection is found in the developmental resistance to the myxoma virus by rabbits in Australia, England and France (Goater and Holmes, 1987; Allison, 1982). When first introduced, the myxoma virus was extremely virulent in rabbit populations. This virulence dropped dramatically in each location as distinct populations developed resistance (Goater and Holmes, 1987). Similar resistance has developed in indigenous birds introduced to avian malaria by temporarily sympatric migratory birds (Warner, 1968; Van Riper et al., 1986).

Population Explosions and Associated Risks

In humans, emergent diseases such as human immunodeficiency virus (HIV) and Ebola are extremely virulent. HIV or a similar virus probably emerged and became established in humans approximately 100 years ago (May and Anderson, 1990). Increased reproductive success of this virus is attributable to favorable genetic mutations and human population density (May and Anderson, 1990). To be successful (virulent), parasites require access to populations who frequently contact others in order to improve the chances of exposure to naïve populations. High population densities are extremely beneficial to parasites for facilitating transmission and providing a large and plentiful environment to exploit.

Parasitic infections challenge host immune systems and often stimulate short-term adaptive mechanisms and/or long-term changes in a host population's genetic codes (Sitepu and Dobson, 1982). A vertebrate host's immune system can be roughly subdivided into two categories: the innate immune system and the acquired immune system/response. The innate immune system effectively distinguishes biological material as "self" or "non-self" (Wakelin and Apanius, 1997). Thus, the innate immune system can be expressed by a spectrum of defensive cells such as macrophages and granulocytes, which effectively identify foreign invaders (non-self) and have a direct toxic effect upon them (Wakelin and Apanius, 1997).

Acquired immunity discriminates between the vast numbers of foreign invaders with exact specificity by binding onto a specific site on the antigen (Wakelin and Apanius, 1997). Since acquired immunities require changes at the molecular level, genetic changes play an effective role, thus protecting the host against parasitic maladies and leading to genetic polymorphism in the breeding population (Wakelin and Apanius, 1997). These

polymorphisms are important for allelic variation, which can benefit the host's offspring (Wakelin and Apanius, 1997). However, the short life spans and high reproductive output of most parasites, combined with the high degree of biological variation, often counteract immunological defenses of hosts and act to continue the biological "arms race" in the interactions between hosts and parasites (Van Valen, 1973).

2.6 Behavioral Responses to Parasites

Parasites in Social Groups

Mammals are exposed to a diverse gamut of macro and microparasites. Any species that lives in a social group or in a location with a high population density of conspecifics, such as chimpanzees, are theoretically increasing the likelihood of acquiring a parasite and/or transmitting a parasite that it is harboring (Loehle, 1994). It is expected that an increase in the frequency and duration of close proximity and/or contact with members of the same species will result in increased opportunities for pathogen transmission and parasite acquisition (Loehle, 1994). Therefore, animals residing in social groups should harbor a higher prevalence and wider spectrum of parasitic diversity compared to solitary animals (Altizer et al., 2003). Similarly, host sociality and degree of gregariousness should translate into higher parasite prevalence, intensity, and diversity (Möller et al., 1993). If social interactions are opportunities for parasites to disperse, we would expect that monogamous or solitary animals are burdened less by parasites (Altizer et al., 2003). Compared to other mammalian orders, primates are highly social. Chimpanzees as described as highly gregarious group living primates with intricate social bonds (Goodall, 1986), thus chimpanzees and other primates may be at greater risk of parasitic infection than solitary animals (Altizer et al., 2003).

Nunn et al. (2003) analyzed 941 host-parasite combinations that included 101 haplorhine species of primates and 231 parasite species. They concluded that host population density was the key determinant of parasite spread. The authors warn that other variables are intrinsic in this analysis, such as phylogenetic relationships and body size. In other words, closely related species should harbor similar parasites. Furthermore, if hosts are considered “ecosystems” a larger body should harbor a higher parasite load and increased parasite diversity (Kuris et al., 1980). This research has clear implications for parasitic interactions between humans and chimpanzees, two closely-related and large-bodied species.

Freeland’s (1976) pioneering work suggested that primates increase their fitness by patterning their behavior and social interactions in ways that minimize the exposure of acquiring new parasites and eliminating the parasite loads that they already harbor. Pathogens and the probability of acquiring a pathogen(s) are fundamentally important in group size and composition. Furthermore, diseases are more problematic to conspecifics than to other sympatric species (Freeland, 1976).

Territoriality

Compared to solitary animals, gregarious species such as chimpanzees are expected to have a greater prevalence and spectrum of parasites due to the increased frequency and duration of close proximity between individuals (Loehle, 1994). Using these principles as a foundation, territories should be guarded to keep conspecifics or groups of conspecifics outside of an incumbent group’s homerange and core areas (Freeland, 1976). Groups should therefore be vigilant and protective of homeranges in order to defend contested resources and to eliminate the possibility of acquiring parasites from outside groups or solitary individuals (Freeland, 1976; Moore, 2002). Recent immigrants have less access to quality foods and

reduced overall feeding efficiency compared to higher-ranking long term residents (Fuentes, pers. com). Good nutrition may convolute symptoms of disease. Thus, peripheralized animals with poor nutrition are expected to manifest signals of poor health visually or olfactorally. These cues allow the established social group to determine if the potential immigrant harbors a parasitic insult (Freeland, 1976).

Social groups of animals can avoid parasites by overt behavioral modifications (Freeland, 1976; 1983). According to Hausfater and Meade (1982), groups should move away from fecal matter or regions in the home range that are contaminated. Sleeping sites should be rotated to reduce the exposure to parasites. Females should engage in female choice before mating, and group size should be determined by group parasitic infections and the prevalence of parasites in the group's home range (Freeland, 1976; Hausfater and Meade, 1982; Hahn et al., 2003). This hypothesis has been supported in mangabeys (*Cercocebus albigena*; Freeland, 1980).

2.7 Sex, Parasites and Microscopes: The Origins of Sexual Reproduction

Theories regarding the origin, evolution, and maintenance of sexual reproduction are attributed to the selective forces of parasites (Van Valen, 1973; Paul, 2002). The best known hypothesis regarding parasitic selective pressures concerning sexual reproduction is the “Red Queen Hypothesis.” The Red Queen Hypothesis is an evolutionary supposition that explains the advantages of sexual reproduction (Van Valen, 1973).

The Red Queen hypothesis was developed as an ecological and evolutionary metaphor to Alice's experiences in Lewis Carroll's *Through the Looking Glass*. Alice meets the Red Queen and begins to chase her, although no matter how hard she runs she is unable to make any distance. In response to Alice's frustrations, the Red Queen quips, “now...you

see, it takes all the running you can do to keep in the same place” (Carroll, 1872 [1998]). This is analogous to the need of species to “run” or evolve to simply stay in the “same place” or remain “living or extant” (Van Valen, 1973). Sexual reproduction results in a genetically unique individual, a natural experiment and a new ecosystem leading to variation of the gene pool and individuals within a population.

The Red Queen Hypothesis has been used to discuss the coevolution of hosts and parasites and subsequent oscillations in genetic frequencies and the perpetuation of sexual reproduction (Bell, 1982). Sexual reproduction simultaneously creates genetic variation and, in essence, a new environment that may effectively dissuade parasitic virulence or transmission. Clearly, rates of reproduction and sexual development of hosts are much slower than those of the parasites and affect the speed at which host populations can respond to parasitic infestations (Paul, 2002). Thus, parasites are able to respond to their host populations’ genetic polymorphisms faster than their hosts are able to adapt. In other words, the interplay between hosts and parasites results in a perpetual coevolutionary arms race (Van Valen, 1973).

Sexual Selection and Secondary Sexual Characteristics

In addition to supporting sexual reproduction, parasites may drive sexual selection and development of secondary sexual characteristics (Hamilton and Zuk, 1982). Secondary sexual characteristics and lengthy courtship displays of males require large energetic investments and have been shown to be effective in attracting females (Zuk, 1992). If ornaments, bright colors, elaborate behavioral displays, acoustic calls, or other forms of secondary sexual characters are indicators of good health and vigor, females should choose

those males with the most impressive attributes. As mentioned previously, parasitic infection can be physically and olfactorally manifested.

Secondary sexual characteristics communicate a male's ability to effectively resist parasitic infections and display their current health and genetic vigor via costly ornaments or extravagant behaviors (Hamilton and Zuk, 1982). Females, in turn, should choose males that engage in lengthy behavioral displays and exhibit "flashy" ornaments, as parasite infested males would appear more "drab" and incapable of costly courtship displays (Zuk, 1992). Physical or behavioral indicators of health should communicate to the female that an uninfected male can provide effective parenting, can effectively defeat contagion(s), will provide his offspring with genetic resistance to future parasitic infections, and will not transmit parasitic infections to the female via copulation or intimate proximity (Möller, 1997; Möller and Saino, 1994).

To test this hypothesis, Hamilton and Zuk (1982) compared the blood parasites, protozoans, and nematodes of North American passerines. These results were combined with information on several sexual characteristics, including male and female brightness and the male's song (Hamilton and Zuk, 1982). The authors' results suggested that bright bird species harbored more parasites. However, the brightest males of already bright species were found to possess lower parasite loads (as compared to conspecifics). This suggests that sexual selection is in part driven by parasites (Zuk, 1992). Similar studies have tested the Hamilton-Zuk hypothesis using fish and other species of birds with general agreements in their results (Zuk, 1992).

Further direct evidence for parasite-mediated sexual selection comes from carotenoids (Zuk, 1992; Lozano, 1994). Carotenoids are pigments that are responsible for the

red and yellow colorings found in most vertebrate and invertebrate animals (Zuk, 1992). These pigments are expressions of an animal's nutritional status, rather than metabolism (Zuk, 1992). Thus, the absence, presence, or intensity of the coloration is dependent on diet and access to a stable food supply. In short, carotenoid pigments are rude indicators of health in many yellow and/or red accented animals. Carotenoid-pigmented characteristics are therefore condition-dependent indicators of health that have a special role in sexual selection (Zuk, 1992; Lozano, 1994). A study of house finches (*Carpodacus mexicanus*) revealed the females chose the "reddest" and most brilliantly colored males to mate with (Hill, 1990). These results suggest that females preferred males with a good health profile via secondary sexual characteristics that probably inhabit a home range with access to high-quality foods. Because carotenoid pigmented traits are dependent on environmental factors, substandard males cannot "cheat" and produce bright colors via other means.

Sexual Promiscuity in Social Groups

Sexual promiscuity is common in social animals. The benefits of promiscuity to females are female choice (Small, 1989) and male protection of offspring through mechanisms of paternity confusion (Borries, 1992). In promiscuous mating systems, like that of chimpanzees, males are unable to be certain of which immatures they have sired (Goodall, 1986). Theoretically this uncertainty provides protection against infanticide and leads to male investment in non-kin (Dolhinow, 1999). This mating system is beneficial to a male (particularly dominant or high-ranking males) by allowing him to mate with several females and potentially improving his reproductive success (Trivers, 1972). However, the consequences of multiple mating partners can be harmful if an animal acquires a sexually transmitted disease.

Sexually transmitted diseases (STD) are ubiquitous in animal groups (Nunn et al., 2003) and recent comparative studies have documented over 200 sexually transmitted diseases in 27 orders of animals (Lockhart et al., 1996). In humans, this is best illustrated by the HIV/AIDS epidemic. HIV/AIDS is not visually or physically detectable until the later stages of infection, in which case its human host may exhibit disease and/or emaciation. The delayed physical manifestation of HIV/AIDS provides abundant time for the virus to spread before detection. As a global community, we have recognized that the only way to halt the spread of the disease is to modify sexual behaviors with the use of prophylactics and abstinence.

Nonhuman vertebrate hosts also use behavioral modifications to alter the impact of parasites. These include two broad counterstrategies against sexually transmitted diseases: immune defenses and behavioral defenses (Nunn et al., 2000). Nunn et al. (2000) found that animals that engage in sexually promiscuous mating patterns had developed higher leukocyte counts. Leukocytes (types of white blood cells) are an immune component that acts as a physiological barrier to sexually transmitted diseases.

Nunn (2003) developed and tested four behavioral strategies used by nonhuman primates to eliminate parasites. Genital inspection is a preventative behavioral measure against sexually transmitted disease (STD; Nunn, 2003). The active inspection of the genitalia of males and females personally or by conspecifics helps identify ectoparasites in addition to topical infections associated with microparasites (Nunn, 2003). Inspecting potentially sexual partners for STDs may also reduce the likelihood of acquiring parasitic infections. This behavior has been described in chimpanzees (Goodall, 1986).

The most common result of sexually transmitted diseases is sterility (Hudson and Dobson, 1997). Although sterility is detrimental to the host, it can be beneficial to parasites in two ways: sterile animals may mate continuously in order to increase their reproductive success and, subsequently, infect each mating partner with the sexually transmitted disease (Hudson and Dobson, 1997). An alternative strategy, theoretically utilized by a parasite, is to reduce the host's sexual drive (Zuk, 1992).

Animals in promiscuous mating systems expend tremendous amounts of energy in improving their reproductive success. These energetic investments include courtship displays, achieving high social status, building a den or shelter, protection of sexual partners from conspecifics, protecting offspring from predators and conspecifics, and investment in energetically expensive secondary sexual characteristics (Zuk, 1992). Several behavioral investments can be costly (defense of offspring and mates) and may have severe deleterious consequences, namely injury or death (Williams et al., 2004). Since, parasites use their definitive host as a source of food, shelter, and dispersers of their offspring, any negative consequences (mortality and mobility) associated with the host sexual behavior can be lethal.

A reduction in the host's sexual drive should theoretically benefit the parasite, as the host should be prone to investing its time and energy into increasing its feeding efficiency and not engage in risky and dangerous behaviors associated with mating (Zuk, 1992). Such behaviors include male-male fighting for mates, defensive behaviors against male influxes, or female competition for copulation with high-ranking males. Thus, the derived benefits to the parasite are measured in obtaining resources from their host and modifying their host's behavior by reducing engagement in potentially "risky" mating behaviors (Moore, 2002; Möller, 1997; Perrin et al., 1996).

2.8 Conclusion

Parasites occupy a liberal spectrum of environments, are found in nearly every ecosystem, and affect all multi-cellular species. However, their extensive distribution throughout abiotic and biotic systems are frequently overlooked in discussions of ecosystem health and host behavior. Although difficult to measure, coevolution between parasites and their hosts may have played a key role in regulating hosts, both behaviorally and physiologically. In addition to regulating population sizes, demographic organization and immigration, parasitic pressures may have played a key role in mammalian evolution and sexual reproduction. As a natural part of a healthy ecosystem, disease ecology can act as an indicator of systems health and should be considered an important component of animal behavior and physiology.

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Chapter Three

Human and Nonhuman Primate Interactions

3.1 Introduction

For tens of thousands of years, humans and nonhuman primates (NHPs) have lived sympatrically throughout a multitude of landscapes (Strier, 2002). These interactions have resulted in a mosaic of interspecies behaviors that have affected these species' dynamics historically, environmentally and demographically (Strier, 2002). Although such interactions can be classified on a spectrum that ranges from important religious icons to economic products, much of the research regarding this interface has focused on the devastating effects of humans on NHP populations.

Heavily focusing on the negative aspects of human and NHP interactions can glaze over the complex role of humans as vital elements within NHP environments. Instead of presenting this relationship as singularly destructive, it is possible to view humans and NHPs as co-participants in rapidly escalating realms of culture and ecological change (Fuentes and Wolfe, 2002). Utilizing cultural ecology, anthropologists can better understand the interactions of local people with endemic NHP primate species and simultaneously contribute to our general knowledge of biological and cultural diversity while aiding conservation efforts (Shepard, 2002). In addition to the gains made in understanding NHP ecology, ethnoprimateological methodologies provide a broader conceptualization to the context of human ecology (Fuentes and Wolfe, 2002).

3.2 Humans and Nature: A False Dichotomy

Conservation projects are typically promoted through non-government organizations (NGO) such as Conservation International, and intergovernmental

organizations (IGO) such as the World Bank and the United Nations. These organizations are in competition for scarce funding from the public and private sector. As a result, various NGOs and IGOs are forced to decide between the promotion of humans and the health of NHP and their shared landscapes, instead of approaching them as interconnected components of a greater system (McElroy and Townsend, 2004).

This false dichotomy of human and environmental health was not created through financial struggles. Instead it was reified through a series of fundamentalist and historical precedents that support the doctrine of environmental realism, which holds that culture is distinct from nature (Macnaghten and Urry, 1998). It is exemplified by the Christian faith which professes a categorical difference between “man” and animals. According to Genesis (1:28) humans were given dominion over the rest of the earth and its inhabitants. Throughout Christian literature humans are presented outside of nature and all natural events.

Categorization of the dominion of humans over animals became the life work of Carolus Linnaeus (1707-1778), who provided science with the system of binomial nomenclature that is still in use today. In his second edition, Linnaeus separated humans into multiple species based on phenotype and temperament (Linnaeus, 1758). A product of his time, Linnaeus provided scientific “evidence” of the separation between “savage” people and Europeans. Subsequent scientists further reified these differences and created static evolutionary continuums that placed chimpanzees on one end and the European man on the other (e.g., Nott and Gliddon, 1854). The continuum included humans from all over the globe, with Africans as the assumed closest relatives of nonhuman primates, followed by Asians, Middle Easterners and eventually Western Europeans. The effects of this racialization of the human species are still reflected in Western models of humanity (Gould,

1981; Brace, 2005). For instance, less technologically advanced communities who are recognized as being more reliant on nature are commemorated as forest protectors (Reed, 1997). This characterization results in a simplification of complicated relationships that people have with their environments. At its extreme, such people are viewed as ecologically “noble savages” (Redford, 1990).

The ecologically noble savage concept refers to humans in non-industrialized areas of the world who are considered intrinsically more connected with nature. As a result of this deep connection they are thought to possess a greater understanding of nature and are considered to be natural conservationists. Meant to elucidate our ancestral ties with nature, it assumes that when provided the tools for sustainable development these people would happily embrace them (Shepard, 2002). This concept, damaging in its own right, homogenizes non-industrialized people and romanticizes their otherwise multifaceted identities. Instead, non-industrialized people react in diverse ways to their environments, including openly profiting from destructive practices of outsiders, leading destructive practices themselves, and existing sustainably within their environments (Moran, 1993). Whether indigenous peoples are better conservationists than “Westerners” is a moot point. Instead, the true question is how indigenous people can better participate in and benefit from conservation policies and projects for their lands (Shepard 2002).

It is problematic therefore that conservation programs such as Conservation International are increasingly addressing the role of humans in the environment by portraying them as ecologically noble savages (Conklin and Graham, 1995). Additional problems arise with the ethnocentric assumption that nature and the environment are perceived the same cross-culturally. The engagement and response of human beings to nature are embedded in

their daily lives and are ambivalent and highly diverse (Macnaghten and Urry 1998). In other words, instead of a singular, all encompassing 'Nature', there is a diversity of constructed natures created through a series of socio-cultural processes influenced by social values and worldviews (Macnaghten and Urry, 1998; Mcelroy and Townsend, 2004). This contrasts with the view that the environment is a real entity, substantially separate from human experience (Macnaghten and Urry, 1998).

The Western¹ world's reliance on biomedical inquiry continues to dichotomize humans and our environment. Within this paradigm there is a fundamental separation of human cultures from their physical environment (Macnaghten and Urry, 1998). However, studies in nutrition, genetics, epidemiology and public health are built on the assumption that an organism's interaction with its environment results in the ultimate expression of its affected traits (Mcelroy and Townsend, 2004). For example, the response to environmental stressors, such as food availability, climate and disease are believed to play a critical role in an organism's evolution (see Chapter 2; Hunt, 1994; Teaforde and Ungar, 2000; Fish and Lockwood, 2003; Mcelroy and Townsend, 2004).

3.3 Compromising Relationships Between Humans and Nonhuman Primates

The majority of primates today occupy heavily disturbed, anthropogenically modified mosaic landscapes that include human settlements, farmland and isolated protected areas (Chapman et al. 2005; Chapman and Peres, 2001). Increased reliance on modified habitat by NHPs and associated threat of human activities to these primates has been recognized for nearly three decades (Thorington, 1974; Wilson and Wilson, 1975; Chapman and Peres,

¹ In this situation, the Western World refers to Western European countries, The United States of America and Australia.

2001). In this time humans have been held responsible for massive, irrevocable changes to crucial primate habitats (Chapman and Peres, 2001; Chapman et al., 2005).

Development of NHP habitats for the accommodation of burgeoning human communities is likely to continue growing exponentially (Chapman et al., 2005). This anthropogenic modification of primary habitats results in closer, more frequent contact of humans and animals, thus increasing the risk of zoonotic disease transmission (Daszk and Cunningham, 2001; Dobson and Foufopoulos, 2001; Chapman et al., 2005). Escalated risk of transmission between human and NHP creates urgency for information regarding the shared infectious diseases in the latter (Chapman et al., 2005). By increasing our understanding of human behaviors and their associated risks, we can gain insight into the total impact of anthropogenic disturbance on NHPs (Gillespie and Chapman, 2005). It is for these reasons that active monitoring of all studied NHP populations is recommended, regardless of presently perceived threats to them.

3.4 Human Threats to Nonhuman Primate Populations

Failure to address the breadth of relationships present between human and nonhuman primates greatly impedes conservation efforts and may retard our understanding of this dynamic relationship. Although there is a growing body of research that addresses commensal relationships between humans and NHPs (see Fuentes and Wolfe, 2002), threatening relationships are more extensively addressed in the literature. Clearly, those relationships that may limit, threaten or decimate a population are of particular importance for immediate primate conservation initiatives. These include human and NHP responses to deforestation, bushmeat extraction, crop raiding and their impacts on disease transmission (Figure 3.1).

Figure 3.1 Factors Affecting Primate Population Status

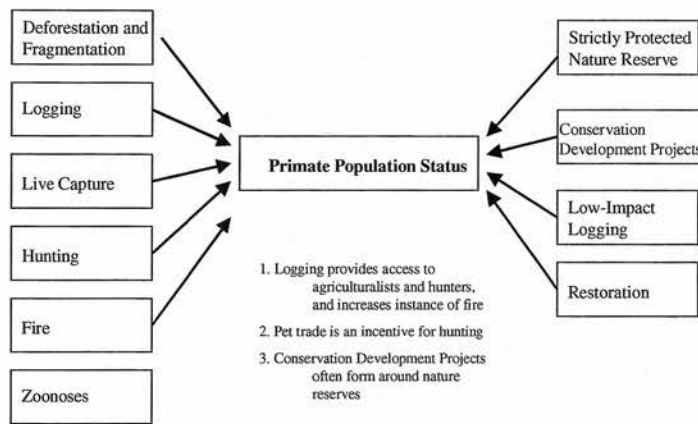


Figure Adapted from Chapman CA, Peres CA. 2001. Primate conservation in the new millennium: the role of scientists. *Evolutionary Anthropology*. 10:16-33

Deforestation

Deforestation and accompanying habitat fragmentation are some of the more dire issues facing extant nonhuman primates (Chapman and Peres, 2001). Loss of habitat due to expanding human populations and intensification of agriculture can lead to serious impacts on NHP behavior, sociality and health. In many parts of the world, the removal of forests and destruction of NHP habitat has resulted in the eradication of entire primate populations (Chapman et al., 1999).

In addition to reducing access to nutritional resources, fragmented habitats can also create genetic islands that result in unhealthy and eventually unstable populations (Chapman and Peres, 2001). Fragmented populations are not only limited genetically but may be a greater risk for disease transmission. The combination of a reduction in homerange size and the breaching of natural barriers of disease transmission leads to intensified contact between humans, NHPs and their waste products.

While habitat fragmentation results in very real risks for NHP in terms of genetic diversity and disease transmission, wide scale timber extraction by large lumber companies also provides access for bushmeat hunting and extraction (Chapman and Peres, 2001). The roads and labor camps constructed by lumber companies provide hunters access to previously impenetrable areas (Nishida et al., 2001). While logging, workers earn extra money by extracting bushmeat and transporting it to local and urban consumers on the logging vehicles (Nishida et al., 2001). In addition to extracting primates and other forest animals for commercial sale, the diets of the employees of logging companies are often supplemented by these, often-rare species (Nishida et al., 2001).

Consumption of Primates

Primate meat, skin, organs and bones are sold in markets from the local to the global level. Although the extraction and consumption of great apes represents a relatively insignificant portion of the total body mass included in the bushmeat trade, its effects on these primates have been devastating (Nishida et al., 2001). The long gestation and interbirth intervals (IBI) of primates in general and great apes specifically prevents their populations from recuperating from this devastating extractive process. This may be of particular concern in West and Central Africa, where the demand for bushmeat is as much as four times greater than that of the Amazon Basin (Wolfe et al., 2005). Thus, the largest primates with the longest IBIs are found where bushmeat extraction is most intense. It is particularly disturbing to note that it is not uncommon for great ape meat to be served as a delicacy in countries that formally embrace conservation initiatives (Farmer, 2002).

Crop Raiding

Another risk to larger bodied primates such as baboons (*Papio hamadryas* sp.) and great apes is their characterization as crop raiders and agricultural pests. Although wild ungulates and smaller mammals such as rodents consume the bulk of raided crops, primates retain a great deal of the blame (Naughton-Treves, 1998). Compared to smaller, more cryptic animals, large bodied primates are more gregarious, making them more visually and audibly noticeable. In Senegal, the presences of chimpanzees in a family field can be regarded as a bad omen associated with sickness and death (Clavette, 2003). To protect their crops, humans employ a range of preemptive strategies that range from poisoning, throwing stones, and shooting NHPs. As with bushmeat hunting the removal of individuals, especially females of reproductive age can be extremely damaging to a population.

Zoonoses

A confounding variable to the damage of deforestation, primate consumption, and consequences of crop raiding on NHP populations is zoonotic disease transmission. Zoonoses are diseases of nonhuman animals that are also transmittable to and from humans (Roberts and Janovy, 2000). Some of these diseases originated from human contact with domesticated animals (Larsen, 2003); others originated through encroachment into tropical “hot spots” (WHO, 2002)². Infectious diseases such as Ebola fever, AIDS and polio have all had devastating effects on NHP and human populations (Wolfe et al., 1998; Gao et al., 1999). In order to build a better understanding of zoonotic disease transmission, a team of specialists

² “Regardless of their origins, infectious diseases are exacerbated by poor diets and compromised nutrition” (Larsen, 2003).

that include veterinarians, physicians, epidemiologists and anthropologists must be mobilized (Stuart and Strier, 1995).

Ebola hemorrhagic fever (Ebola HF) is a viral infection that has the capacity to destroy human and nonhuman primate populations (Peters and LeDuc 1999; WHO, 2002). This often fatal disease is characterized by an abrupt onset of symptoms that include fever, headache, joint and muscle aches, sore throat, and weakness, followed by diarrhea, vomiting, and stomach pain. Some patients also develop a rash, red eyes, hiccups and internal and external bleeding. This disease is commonly spread through contact with an infected person's or animal's secretions (WHO, 2002).

Like many zoonotic diseases, Ebola seems to easily cross the biological barrier between humans and the other great apes. The effects on our closest living relatives, the great apes, may be especially severe, as has been demonstrated in the recent catastrophic decline of great apes in Gabon due to the Ebola virus (Leroy et al., 2004). An outbreak of Ebola in the village of Mayibout in NE Gabon, for example, was linked to the handling, preparation, and consumption of a chimpanzee that had been found dead. Of the 37 identified cases of Ebola in humans, 29 involved direct exposure to the dead chimpanzee (WHO, 2002). In 1994, twelve chimpanzees developed symptoms of Ebola in the Tai Forest, Cote d'Ivoire. All twelve of these chimpanzees later died (Peters and LeDuc, 1999).

Other instances of zoonotic transmission between human and NHPs have also resulted in extensive mortality. In 1966, a catastrophic outbreak of poliomyelitis in chimpanzees at the Gombe Stream Reserve, Tanzania left six chimpanzees dead and another six paralyzed for life (Goodall, 1986; Goodall, 1983). The lack of data regarding chimpanzee health and the health of local fauna makes it impossible to determine if this outbreak was part

of a natural cycle or due to anthropogenic influences (Wallis and Lee, 1999; Wolfe et al., 1998). However, a corresponding polio outbreak in local human populations living on the periphery of the chimpanzees range suggests a human origin of the exposure (Goodall, 1988). Such a disastrous decline highlights the need for baseline health information in order to effectively track and understand hazardous interactions prior to outbreaks (Goodall, 1986; Wolfe et al., 1998). Baseline health information on both local fauna and humans in areas of high and low anthropogenic disturbance would have helped evaluate the pathogenic risks presented to nonhuman primates (Lilly, 2002).

3.5 Great Ape Health Monitoring Unit

Ignoring the physical health of humans can impede all conservation efforts crucial to the survival of the great apes. In response to outbreaks of disease in great apes that has lead to decimation of some populations and the lack of data surrounding them, Dr. Christophe Boesch of the Max Plank Institute initiated the Great Ape Health Monitoring Unit (GAHMU). This unit is building a pan-African database, which includes health information on chimpanzee and gorilla populations in addition to their human counterparts. It is hopeful that a longitudinal database that includes all available information in regards to great ape health can underscore other conservation efforts and provide a measure of community risk.

The purpose of the GAHMU database is to combine the expertise of veterinarians, ecologists, anthropologists, biologists and other specialists in creating a multidisciplinary approach to great ape health that can ultimately contribute to species survival (see Stuart and Strier, 1995). In addition, this project has a multidisciplinary emergency response team comprised of specialists capable of traveling to anywhere in the world within 48 hours of an outbreak. Such immediate reaction to these potentially devastating diseases is critical to both

human and NHP survival. This type of collaborations is encouraging and suggests that a multifaceted response to such integrative problems is possible and practical.

3.6 Cultural Ecology: Benefits of Cultural Anthropology to Primatological Inquiries

Ecology is considered an important aspect of primate behavior and evolution. Studies of primate ecology often focus on interactions between NHPs and “pristine” or non-anthropogenically disturbed environments (Fuentes and Wolfe, 2002). However, whether NHPs are exploited for food or other products, regarded as pests or revered for religious purposes, there is no denying the ecological importance of humans in the lives of NHPs (Strier, 2002). Equally important is the role NHPs play economically and spiritually in the lives of the people with whom they share their home ranges (Strier, 2002).

By combining the study of general ecology with cultural ecology, humans become part of the interconnected environmental system in which NHP are engaged. Cultural ecology encompasses cultural models of the environment and its relationship between people and their ecological space (Fuentes and Wolfe, 2002). A thorough understanding of these models is necessary to build conservation and development strategies that address forest protection and the health of all members of the ecosystem (Wallis and Lee, 1999). If concurrently implemented with techniques of cultural ecology, cultural anthropology is able to offer practical advice regarding strategies of conservation that cater to both human and NHP utilization of land (Dolhinow, 2002). In other words, when humans and NHP ecology and behavior are considered as interconnected units, conservation efforts are most effective (Fuentes and Wolfe, 2002).

Consideration of the complex relationship between humans and NHPs is an important component of this study. Habitat destruction, changing technologies and the unprecedented

growth of human populations can have a tremendous impact on NHP populations and further threaten already endangered chimpanzees (Shepard, 2002). However, by focusing on these extreme and turbulent interaction anthropologists have ignored the complex relationships resulting from circumstances of commensalism and mutualism (Fuentes and Wolfe, 2002). These interactions are frequently less obvious and, thus, make it more difficult to determine the impacts on both species involved.

It is not uncommon for NHP populations living sympatrically with human communities to be dismissed as unnatural. In these situations it is assumed that human interactions are disruptive to otherwise “normal” primate behavioral patterns, and they are ignored or considered less important to our understanding of primate communities (Fuentes, pers. comm.). Instead of dismissing impacted primate communities as uninteresting, uninformative, “ruined” or stagnant, insight into humanity’s relationship with their environment should be approached as an important component of NHP environments (Gillespie and Chapman, 2005).

In biological anthropology, assumptions regarding the insignificance of NHP communities located in non-pristine environments may hinder advances in studies of primate adaptation. Evolutionary research focuses on the dynamic qualities of species that enable them to adapt to a range of social and physical environments. By discarding NHP populations that have contact with humans we fail to address the issue of their adaptation to environmental pressures, in this case a competing species. It is faulty to assume that communities of animals could be static, and the supposition that humans would somehow behaviorally destroy a population simply by being in contact with it is antiquated and severely limiting to our understanding of primate socio and behavioral ecology.

In primatology, humans are often considered superfluous background noise, a logistical complication to primatological fieldwork, or a threat to nonhuman primates (Fuentes and Wolfe, 2002). They are demonized by many conservation programs or are patronized in their roles as “forest protectors” or people of the forest (Clavette, 2003). In reality, human behavior is variable and dynamic and worthy of serious consideration regarding its impact on primate environments, ecologies, and health. It is for these reasons that biological anthropologist studying our closest relatives should consider local human populations as important sources of insight into NHP behavior and welfare.

3.7 Primate Protection and Human Impact

Instead of using the blanket assumption that the presence of humans automatically results in population declines for NHP groups, a closer, more in-depth analysis would suggest that varying cultural beliefs and behaviors can also result in a protective state for NHPs and healthier human populations in some cases. For instance, cultural taboos stigmatizing the consumption of NHPs may simultaneously prevent human exposure to blood-borne pathogens.

The relationship between humans and their environment is a complicated one that encompasses many behavioral, religious, spiritual, medicinal and economic avenues. By utilizing an ethnoprimateological approach scientists are able to gain a greater appreciation of the variability of these relationships. Complex cultural relationships threaded through literature, art, religion and folklore interact with modern economic practices and result in significant strategies of protection for animals in some cases. The importance of gaining a clear understanding of local human responses to wildlife cannot be overstated. In areas where

many different ethnic and social communities utilize the same land, it is critical for researchers to address disparities in belief systems between groups.

Bali: Example of Sympatric Association Between Primates and Humans

Creation myths and cultural taboos that include NHPs can lead to a protective status for otherwise endangered animals. However, the true complexity of these relationships is only revealed using an ethnoprimateological approach (Sponsel, 1997). In Bali, Indonesia there are more than 54 sites of human and long-tailed macaque (*Macaca fascicularis*) sympatry. Wheatley (1999) explained the relationship between humans and NHPs within a religious context by suggesting that the innate sacredness of the macaques lead to their peaceful coexistence with human populations.

Closer examination of the situation between macaques and humans in Bali revealed a much more intricate relationship, which included economic, political, religious and social implications (Loudon et al., in press). Bali is a single polity island less than 145 km across wide, which is predominantly inhabited by individuals who practice Balinese Hinduism. Although Bali maintains a great political and religious homogeneity, Loudon et al. (in press) found wide variation in the relationships between humans and the macaques at the 11 temple complexes included in their study.

The variation in local Balinese attitudes towards these macaques could have arisen for economic reasons. For instance, the economic gain enjoyed by some communities due to monkey-centered tourism has resulted in long term provisioning programs that aid in a protective status for the macaques (Figure 3.1). Monkeys involved in commensalisms with humans demonstrated larger population size, with larger and healthier individuals. In comparison, animals living in areas where tourism is absent are tolerated less and are

frequently physically smaller and less healthy (Loudon et al., in press). Thus, Wheatley's (1999) assertion of innate sacredness is a simplification of a complex dynamic found between the Balinese, their political economy and religion and the macaques. If researchers limited their examination to a single temple community and a single human group they would misinterpret the complex dynamics present across the island and potentially draw erroneous conclusions (Loudon et al., in press).

FIGURE 3.1 A Balinese Woman Provisioning Macaques in Her Temple



Such research has important implications for ethnoprimateological studies in larger geographical areas that support diverse cultures, languages and religions. The impact of humans within various religious, political and economic contexts impact NHP lives. For example the cultural diversity found within the 63 km² home range of the Fongoli community of chimpanzees is relatively high compared to the island of Bali. Thus, it is expected that these differences would manifest themselves in the relationships of humans and chimpanzees within this area.

3.8 Conclusions

Anthropogenic disturbance often provides an assault on NHP populations and intensifies the risk of endangerment and extinction. The impact of humans on NHP populations due to deforestation, habitat encroachment and bushmeat extraction are confounded with zoonotic disease transmission (Wolfe et al., 1998; Gao et al., 1999; Rose, 2000). However, relationships between humans and NHPs are complicated and not necessarily adversarial. In addition to destroying NHP populations, cultural variation in human response can lead to the preservation of land and the animals inhabiting it. It is therefore important for anthropologists studying NHP to consider the significant and multifarious role humans can play in the behavior and ecology of nonhuman primates. Such studies need to include a specific analysis of the relationship between humans and sympatric NHP species. These factors will be discussed in more detail in Chapters five and six.

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Chapter Four

Parasitic Sampling Techniques and Results

“Parasitic disease in association with nutritional deficiencies are the primary killers of humans”
(Robert and Janovy, 2000)

4.1 Introduction

Disease ecology is a complex matrix that includes interactions between biological, social, cultural and environmental conditions that factor into population health. Combined with epidemiology, the study of the distribution of health-related events and conditions and the factors that contribute to such distribution, disease ecology is key to understanding primate health (Robert and Janovy, 2000). However, determining the health of free ranging NHP populations and quantifying patterns of disease prevalence is challenging (Chapman et al., 2005).

Many methodologies for the construction of disease patterns rely on biological sampling, including tissue, blood, membrane, fecal and urine samples. Combined with controlled, replicable field experiments, these biological samples are the most desirable. However, when considering critically endangered, long-lived species such as chimpanzees, it is unacceptable to place them at risk of invasive physical examination. In addition, conducting replicable experiments that measure the social and physical effects of hunting, logging and disease transmission are neither ethical nor feasible (Chapman and Peres, 2001). In these challenging situations, noninvasive fecal collection techniques can offer an alternative method of data collection and quantifying patterns of disease transmission. For example, fecal samples enable conservation scientists to diagnose endoparasitic infections without disrupting the population of interest (Stuart and Strier, 1995; Chapman et al., 2005). By collecting and analyzing fecal materials for parasite loads, anthropologists can gain

insight not only into disease ecology for conservation purposes, but also into basic ecological relations between NHP and their environments (McGrew et al., 1989).

4.2 Combining Methodologies

The combination of cultural and biological anthropological techniques provides researchers with greater flexibility in addressing issues of human and NHP commensalisms. Utilizing several approaches enables the development of a broader ecological picture that can provide a snapshot of disease ecology and risk. This is referred to as triangulation and is a method of testing and confirming hypotheses using qualitative and quantitative methods (Ervin, 2005). Results from these types of tests provide contextual and cultural knowledge to other measurements, thus providing reinforcement of results (Ervin, 2005). In this case, the combination of ethnographic methods (discussed in Chapter 5) and fecal flotation and sedimentation techniques provides a framework in which to better understand each of these aspects of disease ecology.

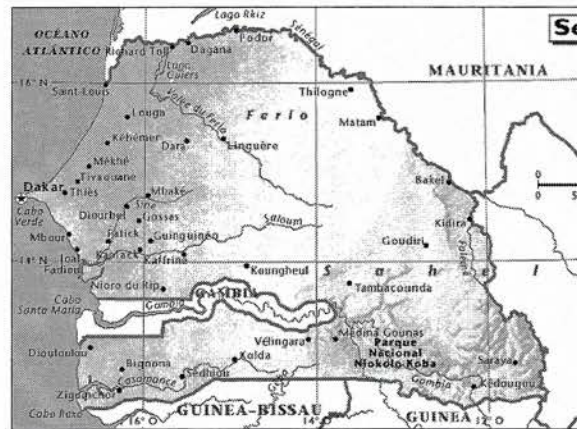
4.3 Study Site

The Mandingue Plateau is situated in southeastern Senegal, southwestern Mali, and northeastern Guinea and encapsulates the Tomboronkoto region of Senegal (Carter et al., 2003). This region of southeastern Senegal represents the northwestern-most extent of chimpanzees' geographical range in Africa. In addition, it is home to the Fongoli community of savanna chimpanzees, the focal community of this research.

Senegal's variable climate and rainfall has resulted in a composite landscape described as a Sudanian-Guinean mosaic habitat (Pruetz, 2006). In southeastern Senegal, the woodland-savanna is parceled by pockets of gallery forest and extensive areas of laterite plateau (McGrew et al., 1981; Hunt and McGrew, 2002). The study site includes the

chimpanzees' 63 sq km home range, with a base camp at the village of Fongoli ($12^{\circ}41''\text{N}$ $12^{\circ}12''\text{W}$). This village is located approximately 6 km northwest of the town of Kedougou, approximately 35 km from the Guinean border and 85 km from the Malian boarder (Piel, 2004; Figure 4.1). Permission to conduct research in the area has been granted to Jill Pruetz by the Department du Eaux et Forets du Senegal, as well as by regional (Arrondissement du Bandafassi) and local village leaders.

FIGURE 4.1 Map of Senegal: Guinea to the South and Mali Directly East of Kedougou



Human Residency in the Chimpanzee Range

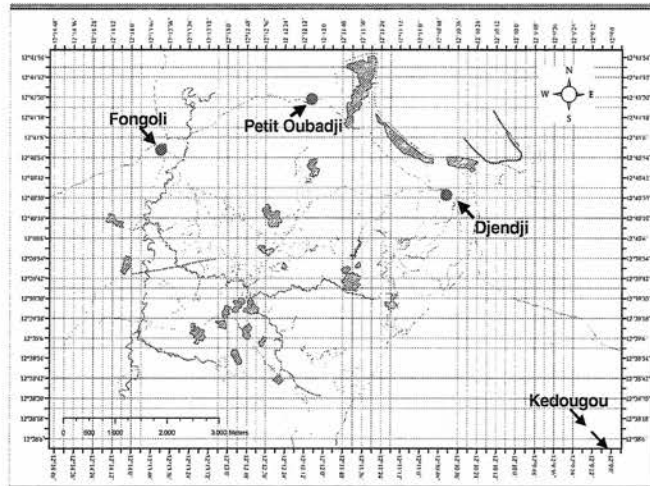
Long-term commensalisms between chimpanzees and humans appear to characterize this region of Senegal. However, resource competition between these two species occurs year round and is thought to peak in the early wet season when key resources are predictably low for all organisms (Duvall, 2001; Pruetz, 2002, Pruetz, 2006). It is estimated that a minimum of 4-5% of the chimpanzees home range has been disturbed by anthropogenic activity (Pruetz, 2006; Figure 4.2). Although much of this disruption has been caused by residents of local villages, residents of Kedougou also utilize this land for agricultural plots (Knutsen,

2003). At this time it is unclear how much the chimpanzees utilize these processed parcels of land.

The demographics within the villages of Fongoli, Petit Oubadji and Djendji were in flux during the period of data collection for this study. Movement into this area from Kedougou and neighboring villages increased around the beginning of the rainy season. This population dynamic occurred due to increased resources in the area due to regular seasonal patterns, including access to water, tillable land and the ripening of *Saba* fruit (*S. senegalensis*). Although no formal study into the demographics of this area has been completed it is estimated that Fongoli, Petit Oubadji and Djendji have approximately 30, 60, and 200+ permanent residents, respectively. Human population in Kedougou and surrounding areas has exploded in the past three decades, with an estimated 91% increase since 1976 (Sall, 2000).

In addition to transforming woodland into agricultural land, humans hunt and consume game from within the chimpanzees' home range. According to Clavette (2003), preferred game of humans in this area includes warthog (*Phacochoerus aethiopicus*) and several species of monkeys (*Chlorocebus aethiops* and *Erythrocebus patas*). Significantly, the hunting and consumption of chimpanzees in this area is avoided due to cultural and religious restrictions (Clavette, 2003; see Chapter 5).

Figure 4.2 Village Placement Within the Fongoli Chimpanzees Homerange



Based on map by P. Bertolani

4.4 Study Subjects

Fongoli Chimpanzees

The Fongoli community is the primary study group for this project and ranges approximately 10km from the town of Kedougou. Less than 400 chimpanzees are estimated to remain in Senegal (Carter et al., 2003). A minimum of 33 individuals (20 males and 13 females) are part of the Fongoli community of chimpanzees, the focus of long-term, continuous study since April, 2001 (Pruetz, 2006). The site is surrounded by settlements of Malinké, Bassari, and Diahanke people.

The region has been described as the hottest, driest, and most open habitat for chimpanzees (McGrew et al., 1981). Extensive *Saba* fruit harvesting has increased human use of this area, and this fruit remains an important source of nutrition for chimpanzees (Pruetz and Knutsen, 2002; Pruetz, 2006). In addition to *Saba* fruit competition, there is

competition over limited water sources during the dry season in this region (Carter et al., 2003).

The Fongoli community represents the only habituated community of savanna dwelling chimpanzees within an active, long-term project, with nest to nest follows increasingly becoming the norm. During the period of data collection, May-August 2005, researchers spent an average of seven hours a day in contact with the chimpanzees (Pruetz, unpublished data). Improvement in the habituation of these animals has important implications for studies addressing disease ecology. As habituation progresses, long-term behavioral data can be added to our understanding of disease contraction and transmission among the chimpanzees.

The present level of habituation enables researchers to follow chimpanzees within 10 meters, but some subjects are more readily observed than others³. At field sites such as the Gombe Stream Reserve, Tanzania where animals were provisioned, are fully habituated, and have been studied for over 40 years, it is possible to collect samples from identified individuals at systematic and regular intervals (Lonsdorf, pers comm.). In addition, each month researchers at this site complete daylong follows of each community member that includes a health assessment (Lonsdorf, pers comm.).

In conditions such as those described for Gombe, researchers are able to construct a strong understanding of community health that can aid experts in risk analysis (Wolfe et al., 1998). It is unfortunate that these conditions were not available for the Fongoli chimpanzees during this study; however, increased habituation of this community has implications in

³ Protocol in regards to following the chimpanzees follows Collins (2003) guidelines to chimpanzee health at the Gombe Stream Reserve. Addition guidelines dictate a maximum of two people are to follow the chimpanzees at a given time. Lactating females in addition to old and crippled individuals are not pursued in order to reduce the physiological and psychological stress that accompanies human observation.

regards to this study. Habituation of these animals results in the identification of individuals and their fecal material, leading to a more precise understanding of disease structure within a community. The collection and analysis of multiple samples from the same individual provides greater insight into parasitic loads that are otherwise affected by variable parasitic shedding.

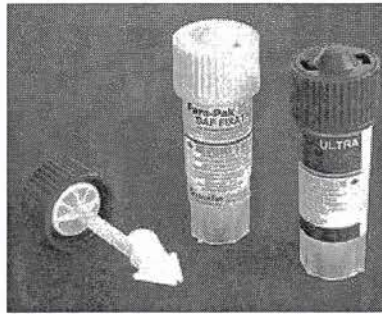
Unlike wet tropical environments, which provide moisture and some protection from the sun, the open woodland mosaic of southeastern Senegal exposes fecal materials directly to destructive elements that lead to desiccation. Prolonged exposure to the elements can destroy evidence of parasitic infection and may result in a false negative. These risks can be mediated, however, by collecting fecal samples promptly after defecation and collecting the specimen from its insulated center. Daily follows of habituated animals increases the potential of collecting fresh, untainted, and non-desiccated samples.

At the time of collection however, the lack of full habituation compromised researcher ability to identify each sample with its expresser. For example, 24 of the 67 samples collected from the Fongoli population during chimpanzee follows are from 9 identified individuals. An additional 8 individuals were identified to their age class. Because individual recognition was not always possible, fresh chimpanzee samples from unknown individuals were collected while following community members.

Fresh fecal materials were collected in 15 mL sterile Para-Pak® Ultra vials alternating between 10% buffered neutral formalin and LV-PVA fixative (See Figure 4.3). These kits were provided by Meridian Bioscience Inc. and were specially designed to preserve ova and parasites found in stool specimens. When possible, the sample was extracted from the inner core of the fecal material to prevent the exposed outer layer from

providing misleading results. The vials contained a collection spoon built into the cap in order to minimize contact with potentially contaminated material. After collecting the specimen researchers were asked to provide the maximum amount of information available regarding its origin. At the minimum, the time and date of collection were recorded, although in some cases more in-depth information regarding sex, age or other identification factors was also included. All samples were collected between May 30, 2005 and August 9, 2005.

Figure 4.3 Para-Pak® Ultra Vials (Middle and Right) With Built in Spoon (Left)



Fongoli chimpanzees rely heavily on *Saba senegalensis*, a fist-sized, tart fruit, for the bulk of their diet during the study period (Pruetz, 2006). The large and numerous seeds of this fruit are swallowed whole in the course of consumption. The seed's tough testa (seed coat) prevents the *Saba* seed from being fully digested, resulting in the entire seed being expelled with feces. This type of behavior results in fecal samples laden with seeds.

This heavy reliance on *Saba* results in distinctive shape and distribution of chimpanzee fecal material. No other large nonhuman mammals swallow *Saba* seeds whole besides chimpanzees and baboons; thus chimpanzee feces is fairly species-typical. All researchers involved in fecal collection were previously trained in distinguishing between the three most similar fecal matters, those of human, baboon and chimpanzees. The feces of domesticated animals are different from all three of these primates, and there is little chance

that a trained individual would make such a mistake. If there was doubt, researchers were asked to not collect the sample.

Human Samples

Both men and women use the chimpanzees' home range to tend to agricultural plots, travel to neighboring villages and to collect *Saba*. Just as *Saba* is heavily exploited by chimpanzees and an important source of nutrition, especially in the dry season, this fruit supplements the local people financially and nutritionally in times of resource scarcity (Pruetz and Knutsen, 2002; Knutsen, 2003; Pruetz, 2006). The sustainability of this resource may be affected by the increased extraction of this fruit by ever increasing human populations. Anthropogenic disturbance within the chimpanzees' 63km² home range is currently estimated at a minimum 4-5% (Pruetz, 2006). This disturbance mostly takes the form of slash and burn agriculture activity by inhabitants of the local villages of Fongoli, Petit Oubadji and Djendji (Pruetz, unpublished data).

Although humans at this site rarely hunt chimpanzees, both humans and chimpanzees compete for the same foods, utilize the same water sources, and contact each other's waste products (see Chapter 5). The use of the chimpanzees' home range for the development of agricultural land, in addition to humans' disposal of fomites, such as food wrappers, tissues and discarded food in these areas theoretically leads to an increased risk of disease transmission between humans and chimpanzees (Wolfe et al., 1998; Roberts and Janovy, 2000). In order to gain an understanding of possible disease transmission between these two species, it was necessary to interview people and collect fecal samples from the Malinké, Bassari, and Diahanke people inhabiting the villages of Fongoli, Petit Oubadji and Djendji, respectively. These three villages were of particular interest to this study because of their

frequent use of land utilized by chimpanzees. More in depth information regarding the interview process is presented in Chapter 5. Cooperation from local human communities ensures that multiple data types can be collected and integrated into a system-wide database.

After concluding the ethnographic interview with people from the villages of Fongoli, Petit Oubadji and Djendji, my research assistant, Mr. Dondo Kante, would explain that we were interested in the health of the people occupying the study area. In order to familiarize individuals with the process, he would discreetly demonstrate the use of the sanitary fecal collection kits from start to finish. These kits were contained in a paper bag and included one Para-Pak® container, a pair of powder free vinyl gloves, and an antibacterial hand wipe. These kits were designed with privacy, confidentiality and ease of use in mind.

Following the advice of Mr. Kante, we did not personally provide fecal collection kits to informants. Instead we hired a literate member of the village with whom my research assistant had a personal relationship to privately contact interested individuals. At one of the villages our colleague was a local health provider; in the other two villages our contact was a well-established and respected community member. Mr. Kante and myself provided training for these three colleagues, which included more in-depth information regarding sanitary collection processes, and we answered any questions that may arose. We then provided enough fecal kits to test the majority of adults within the village.

After researchers left the village, individuals would be contacted regarding possible donation of samples. If they agreed, their name would be written on the Para-Pak® vial (in an attempt to avoid duplication) and, once again, the collection process was explained, with a stress on sanitation. Providers were asked to return their filled vials in addition to all of the

associated garbage, to the village assistant in their paper bags. This not only protected their privacy, but also enabled researchers to remove contaminated waste from the village.

4.5 Analysis of Biological Samples

Sample Analysis

I transported and analyzed preserved samples at the University of Colorado at Boulder and Iowa State University. In the interest of producing comparable results to integrate data into the Great Ape Health Monitoring Unit (GAHMU) database, this project utilized the standardized methodologies developed by Gillespie and Reed (Appendix 1) for fecal collection, fecal floatation and fecal sedimentation. These methods were utilized for both human and chimpanzee specimens and were modified minimally to be applicable to these samples. Although these methods have been tested in rigorous field conditions, minor adaptations were necessary in the collection and processing of the samples⁴. These methods will improve opportunities for longitudinal and comparative studies.

In order to wash the fixative solution from the fecal sample, a gram of material was extracted from the vial. In most chimpanzee specimens the presence of *Saba* seeds in samples provided a challenge for fecal extraction. Feces clung to the testa and were impossible to remove without potentially damaging fragile parasites. Instead, I further homogenized the fecal material with the preservation solution and poured 2mL of this liquid into a 10mL centrifuge tube. After adding distilled water and centrifuging the sample at 1,800 RPM for 10 minutes, the supernatant was poured off and a gram of fecal material remained.

⁴ Modifications in fecal collection are discussed in previous sections. Modifications in the fecal analyses are noted in the following section.

Fecal Flotation

The goal of fecal flotation is to promote the flotation of eggs and cysts to the top of the centrifuge tube, enabling their examination under a microscope. In all samples, one gram of fecal material was combined with distilled water in a 10mL centrifuge tube until it was three-fourths full. This mixture was centrifuged at 1,800 RPM for 10 minutes, after which the supernatant was poured off and discarded. The remaining fecal pellet was then prepared for analysis, utilizing the fecal flotation and fecal sedimentation techniques.

A solution of sodium nitrate (NaNO_3) was used to fill the centrifuge tube to meniscus. The lip of the centrifuge tube was covered by a microscope cover slip, and the sample was again centrifuged at 1,800 RPM for 10 minutes. When completed, the cover slip was removed and immediately placed on a glass slide treated with two droplets of iodine and labeled with the sample number. The iodine acts to stain parasites, making them easier to identify. This slide was then scanned using a 10X objective under a compound microscope in order to isolate parasitic eggs, larvae and cysts. An additional scan using a 40X objective was used to confirm the presence/absence of protozoan cysts. Using an ocular micrometer fitted in the eyepiece of a compound microscope, all parasites, eggs, cysts, and protozoa were measured to the nearest $0.1 \mu\text{m} \pm \text{SD}$ with a 40X objective.

Fecal Sedimentation

Fecal sedimentation accounts for helminthes too heavy to float in a NaNO_3 solution by using the remaining fecal pellet from fecal flotation. In a 50mL beaker, the fecal pellet was suspended in 40ml of sedimentation solution⁵. The homogenized mixture was then

⁵ The sedimentation solution was one part Dawn® dishwashing liquid and six parts distilled water

filtered through a piece of two-ply cheesecloth that was then discarded. The mixture was again filtered through an unused segment of two-ply cheesecloth and set aside to settle.

After the filtered suspension had settled and the sediment became apparent, the supernatant was removed by pipette, and the remaining material was rinsed in a disposable beaker with sedimentation solution. This process was repeated until the supernatant was clear, at which point five drops of sediment were combined with two drops of iodine on a slide labeled with the sample's code. The mixture was then covered by two cover slips placed side by side. This slide was then scanned using a 10X objective, followed by a 40X objective, under a compound microscope in order to isolate helminthes and any additional endoparasites. Using an ocular micrometer fitted in the eyepiece of a compound microscope, all parasites, eggs, cysts, and protozoa were measured to the nearest $0.1\text{ }\mu\text{m}\pm\text{SD}$ with a 40X objective.

4.6 Results of Biological Sampling in Human and Chimpanzee Populations

A total of 100 samples were collected and analyzed from the Fongoli community of chimpanzees (Appendix 2). From the human communities of Fongoli, Petit Oubadji and Djendji, 45 samples were provided and analyzed. Digital photos were taken of all isolated parasites and ova. These photos were labeled with the specimen's number and their size in μm . Dr. Tom Gillespie of the University of Illinois identified individual parasites based on this information. Parasitic identifications are presented in Table 4.1, and photos of specimens are presented in Appendix 3.

Table 4.1 Presence of Parasites in the Study Populations

<i>Pan troglodytes verus</i>			
Individual	Collection	Identification	Possible Species
F117	7/10/2006	Strongylodes Egg	<i>Strongyloides fülleborni</i>
			<i>Strongyloides stercoralis</i>
F101	8/9/2006	Hymenolepis Egg	<i>Hymenolepis nana</i>
F81	6/22/2005	Capillaria Egg	<i>Capillaria hepatica</i>
F106	8/6/2005	Ascarid Egg	Intestinal Roundworm
		Fluke Egg	<i>Schistosoma mansoni</i>
			<i>Schistosoma haematobium</i>
F108	7/23/2005	Strongylodes Egg	<i>Strongyloides fülleborni</i>
			<i>Strongyloides stercoralis</i>
F99	7/10/2005	Tape Worm Egg	Cestoda
<i>Homo sapiens</i>			
		Identification	Possible Species
DJ19		Nematode Larvae -Strongylodes	<i>Strongyloides fülleborni</i>
			<i>Strongyloides stercoralis</i>
PO3		Fluke Egg	<i>Schistosoma mansoni</i>
			<i>Schistosoma haematobium</i>
		Tape Worm Egg	Cestoda
DJ17		Tape Worm Egg	Cestoda

4.7 Presence and Absence of Parasites

Parasitic presence and absence was determined for the Fongoli community of chimpanzees and the human communities of Fongoli, Petit Oubadji and Djendji. Parasites are found in all ecosystems and do not necessarily indicate unhealthy populations (Roberts and Janovy, 2000; Bogitsh et al., 2005). However, when combined with nutritional stresses and unsanitary conditions, parasites can exact a deadly force on their hosts.

Only six of the 100 fecal samples collected and analyzed from the Fongoli community of chimpanzees tested positive for parasitic infection. Surprisingly, there was little overlap in the parasites of these chimpanzees save for a *Strongylodes* infection in F108

and F117. Although it is likely that these infections are of the same species of *Strongylodes*, analyses were inconclusive beyond the genus level. Previously reported parasites of chimpanzees are presented in Appendix 4. Parasites specific to this study are discussed in section 4.9.

Of the 45 human samples analyzed, only three were positive for parasites. Although three communities were tested, results indicate that only one individual from Petit Oubadji and two from Djendji tested positive for gastrointestinal parasites. These individuals did not report currently suffering from disease. In contrast, none of the samples from the Fongoli humans tested positive. An individual from Djendji and another from Petit Oubadji were both infected with Cestoda, although it is unclear what species they are suffering. The villages of Petit Oubadji and Djendji have a larger population than does the village of Fongoli (60, 300, 30 residents respectively). As a result, more people were tested in these first two villages than in the latter (14, 26 and 5 respectively).

Limitations of Study and Factors Affecting Parasite Loads

The numerous samples which tested negative may be reflective of a parasites lifecycle where eggs and adults were not expressed. Most telling of this is specimen F99, collected from a sub-adult male named Nyegi. Although five samples were collected from this individual, only one tested positive for infection. All four of the samples that tested negative were collected within a 31-day period following the collection of the single positive sample. Unless treated with anti-parasitic medication, Nyegi's Cestoda infection would have perpetuated beyond the day he tested positive. This disparity may be explained by the parasite's life cycle. Nyegi's parasites may not have been shedding when the other four samples were collected, thus making them a false negative. It is unlikely that Nyegi's

adolescence has an effect on his propensity for infection (Muehlenbein, 2006). Similar situation may be occurring in other animals; however it is difficult to determine without host identifications. Additionally, Fongoli chimpanzees have been observed to exhibit behaviors consistent with self-medication as demonstrated at other chimpanzee sites.

The lack of positive parasite values in Fongoli chimpanzees may be due to several environmental constraints. The dryness of the site may reduce the diversity and prevalence of infection (Gillespie, pers. comm.). Samples desiccated quickly in the intense heat and open habitat. It is possible that the lifecycles of potential parasites were cut short when their eggs were exposed to the intense environmental conditions or not retrieved by a suitable host in time. In addition, the low density of chimpanzees at this site (Pruetz et al., 2002) may affect the diversity and prevalence of parasites (Gillespie, pers. comm.). Without a large population, parasites may be unable to thrive.

The primary goal of this study was to provide a baseline of human and chimpanzee parasitic infection for use by future researchers and health care professionals. Although the project was a success in this respect, a note of caution is necessary in the interpretation of these results. The lack of parasitic diversity in these two species can be influenced by multiple collection, and behavioral and environmental variables. As with any study, human error can affect results. This study is reliant on the collection of fresh, untainted fecal samples from both chimpanzees and humans. As discussed in previous chapters, researchers relied on visual cues to determine the age of unidentifiable chimpanzee samples. If some of the samples were older than initially thought, delicate eggs may have desiccated without a trace. This issue can be remedied to some degree with the increased habituation of these chimpanzees. In addition, there is no way to know if samples collected blind (without

identification of the owner) came from a variety of individuals or a small few. This concern however, was addressed with a representative sample size.

Human samples were collected after their owners were briefed on collection protocols. Although my research assistant and I trained each village representative on collection techniques, it is unknown how well they were able to transmit this information to those providing the samples. Three of the para-pacs returned by humans were filled with urine instead of feces, suggesting a misinterpretation of the directions.

The collection techniques of both humans' and chimpanzees' samples may have affected the results of this study. However, uncontrollable environmental factors may have also factored into false negatives. The most obvious is the effects of heat and open environment on the chimpanzee samples, although most samples were collected during the rainy season. Desiccation previous to collection may have destroyed fragile parasites. Another variable that may have affected these results is the stage of the life cycle characterizing the parasite. Parasites do not shed continually in order to determine the true spectrum of diversity, samples should ideally be collected from the same individual at varying times during the month.

In Chapter 5, I discuss medical plurality and the range of treatments used by humans to treat stomach discomfort. It is entirely possible that those who provided samples have recently taken medication alleviating them of offending parasites. Similarly, chimpanzees are known to self medicate (Huffman et al., 1997). Although it is unclear how often the Fongoli community chimpanzees exhibit such behavior, five of the 100 samples from chimpanzees included whole leaf swallowing indicative of self-medication. The majority of chimpanzee fecal samples also included large *Saba* seeds that may have inadvertently acted to dislodge

parasites from their intestinal tract (Garber and Kitron, 1997). Although there is little cross-over regarding the diversity of endoparasites shared by humans and chimpanzees in this area of southeastern Senegal, the risk of transmission is high. It is important, therefore, for scientists in this area to continue monitoring chimpanzees and humans for parasites.

4.8 Zoonotic Disease Transmission and Directionality

The results of this study indicate that both humans and chimpanzees at the Fongoli study site tested positive for Cestoda, Trematoda, and Strongylodes. It is understood that humans and chimpanzees share their susceptibility to similar pathogenic infections (Wallis and Lee, 1999); however, it was impossible in this study to determine directionality of disease transmission. In addition, the lack of species-level identifications challenges any assumptions of shared parasitic infections. It is entirely possible that, in some of these cases, the initial infections of humans and chimpanzees originated from neither species and perhaps arose from other animals in the area. However, these questions are beyond the scope of this research.

4.9 Reproduction and Likely Taxonomy of Human and Chimpanzee Infection

Although species-level identification is preferable in studies such as this, information regarding possible routes of infection and disease transmission is also useful in order to understand the types of contact that may put chimpanzees and humans at risk of infection. From genus-level information it is possible to hypothesize possible infections that may be affecting chimpanzees and humans in southeastern Senegal, utilizing information regarding preferable hosts and geographic spread of infection. Table 4.3 provides taxonomic information regarding the identified parasites and their possible species association.

Phylum Platyhelminythes – The Flat Worms

The Platyhelminythes (flat worms) are comprised of four classes, which include the Trematoda (flukes) and the Cestoda (tapeworms). Flatworms are hermaphroditic, however; they do not fertilize their own eggs (Campbell and Reece, 2002). Cestoda live in the digestive tracts of vertebrate hosts as adults and move throughout the body while developing. Their parasitic reliance on vital nutrients predigested by the host can lead to malnutrition and wasting in their hosts (Campbell and Reece, 2002).

Four of the individuals who tested positive for infection suffered from Cestodas (chimpanzees: F101, F99-Nyegi; Humans: PO3, DJ17). One of these samples was identified as *Hymenolepis* and is likely to be either *Hymenolepis nana* or *Hymenolepis diminuta* because of their known parasitism of humans. *Hymenolepis nana* is one of the most common cestods of humans in the world (Schmidt and Robert, 2000). Although the life cycle of *H. nana* can be completed in the bowel, infected persons' feces contain the infectious eggs (Schmidt and Robert, 2000). These eggs are ingested by insects, who infect materials, and they may later be ingested by the host. *Hymenolepis nana* infections in humans are far more common than *H. diminuta* because, in addition to being spread through an intermediate host (insect), it can spread from person to person by eggs in feces (Bogitsh et al., 2005).

After infection, *H. nana* can complete its entire lifecycle within the definitive host's gastrointestinal tract. Thus infection can persist for years. This species is able to grow in conditions of high population density, close contact and in poor sanitary conditions (Bogitsh et al., 2005). Symptomatic individuals are typically those with heavy infection or with compromised immune systems. Symptoms of *H. nana* in humans include gastrointestinal discomfort, diarrhea, weakness, and poor appetite (Schmidt and Robert, 2000).

Table 4.2 Taxonomic Organization of Parasites

Sample F101	
Phylum:	Platyhelminthes
Class:	Cestoidea
Subclass:	Eucestoda
Order:	Cyclophylliidea
Possible Genus:	<i>Hymenolepis nana</i>
Samples F106, PO3	
Phylum:	Platyhelminthes
Class:	Trematoda
Subclass:	Digenea
Order:	Strigeiformes
Family:	Schistosomatidae
Genus:	Schistosoma
Possible Species:	<i>Schistosoma mansoni</i> <i>Schistosoma haematobium</i>
Samples F117, F108, DJ19	
Phylum:	Nematoda
Class:	Secernenta
Subclass:	Rhabditida
Family:	Strongyloididae
Genus:	Strongyloides (Thread worm)
Possible Species:	<i>Strongyloides fülleborni</i> <i>Strongyloides stercoralis</i>
Samples F81	
Phylum:	Nematoda
Class:	Aphasmida
Subclass:	Aphasmida
Family:	Trichurida
Family:	Capillaridae
Possible Species:	<i>Capillaria hepatica</i> <i>Capillaria aerophila</i>
Sample F106	
Phylum:	Nematoda
Class:	
Order:	Ascaridida
Family:	Ascarididae
Possible Species:	<i>Ascaris lumbricoides</i>

A human (PO3) and a chimpanzee sample (F106) tested positive for schistosomes, or blood flukes. Schistosomiasis, the disease caused by these flukes, is endemic in 74 developing countries and infects more than 200 million people in peri-urban and rural areas (Gibson et al., 2002). Of those infected, 120 million are symptomatic, whereas 20 million

suffer severe consequences from the disease. An additional 500-600 million people are at risk of the disease due to poor sanitation and health care (Gibson et al., 2002). These blood-flukes are considered by the World Health Organization to be the most important human helminth and are second in importance only to malaria in terms of socio-economic and public health importance in tropical and sub-tropical areas (World Health Organization, 1996).

Schistosomes have complex life cycles involving multiple hosts. Infected hosts pass schistosome eggs in their feces and urine, which hatch into free-swimming miracidia when exposed to fresh water. The miracidia penetrate molluscs and develop into sporocysts. The sporocysts divide through mitosis and develop into rediae, which become the free-swimming cercariae, rupture the body wall of their intermediate host, and seek out its definitive host (Bogitsh et al., 2005; Schmidt and Robert, 2000). Schistosomes burrow into their host's skin using a series of enzymes (Gibson et al., 2002).

The three species of schistosomes likely to be the infective agents in this area are *Schistosoma mansoni*, *Schistosoma haematobium*, and *Schistosoma intercalatum*. Symptoms of schistosomiasis typically manifest four to six weeks after infection and can include a scabies-like rash, fever, aching, cough, diarrhea or gland enlargement (Bogitsh et al., 2005).

Phylum Nematoda

The phylum Nematoda includes the genus *Strongyloides*, *Capillaridae*, and *Ascaris*. Evidence of *Strongyloides*, or threadworms, was found in two chimpanzees (F117 and F108) and in one human sample (DJ19). Due to host preferences and geography, it is likely that individuals who tested positive for this infection have either *Strongyloides stercoralis* or *Strongyloides fülleborni*. Both of these species are known to infect humans and NHPs (Schmidt and Robert, 2000).

The *Strongyloides* life cycle is complex compared to other nematodes in that it includes free-living and parasitic cycles and has the potential for autoinfection and multiplication within the host. The free-living cycle of *Strongyloides* begins when the rhabditiform larvae are passed in the stool and contaminate soil (Bogitsh et al., 2005). If this larvae molts twice it directly develops into infective filariform larvae; if it molts four times, it matures into free living males and females who produce the rhabditiform larvae. The filariform larvae penetrate the host's skin, which initiates the parasitic cycle (Schmidt and Robert, 2000).

After the filariform larvae penetrate the skin of their host they are transported to the lungs and penetrate the alveolar spaces, eventually moving through the bronchial tree to the pharynx. Its presence in the pharynx stimulates the host to cough and reflexively swallow the larvae (Bogitsh et al., 2005). They travel to the small intestine where they molt twice, develop into sexually mature females, and produce rhabditiform larvae, which are passed in the feces or cause autoinfection in the case of *Strongyloides stercoralis* (human parasitic threadworm) (Bogitsh et al., 2005). Auto infection can occur when, previous to excretion, the larvae penetrate the walls of the lower colon or the skin of the perianal region and reenter the circulation system.

Autoinfection can explain hyperinfections in immunodepressed individuals that present with abdominal pain, shock, distension and, septicemia, in addition to pulmonary and neurologic complication and, in extreme cases, death (Bogitsh et al., 2005). However, many cases are asymptomatic or include abdominal pain, diarrhea, and urticarial rashes on the buttocks and waist areas. *Strongyloides* can be present in both respiratory and gastrointestinal symptoms and has been found in humans up to 50 years after first being exposed (Schmidt

and Robert, 2000). Although adult worms can be killed by antiparasitic medication, larvae migrating throughout the body are unaffected by such treatment.

Evidence for *Capillaria* was found in one of the chimpanzees in this study (F81). The most likely species of infection are *C. hepatica* and *C. aerophila*. These parasites are primarily found in rodents; however, cases have been reported in canines and humans (Schmidt and Robert, 2000). Once infected, adults reside in the host's liver where they lay their eggs. These eggs can be released when an infected host is eaten by a predator, is passed in their feces, and embryonates in the soil. Once ingested by the next host, the eggs hatch in the small intestine where they enter the blood stream and are transported to the liver where they grow into adults (Schmidt and Robert, 2000). This life cycle is slightly different in *C. aerophila*, where adult worms reside in the epithelium of the tracheo-bronchial tract of various animals. They release their eggs, which are coughed up and swallowed by the host and later excreted in their feces and then embryonate in the soil (Bogitsh et al., 2005; Schmidt and Robert, 2000).

One chimpanzee (F106) resulted in a positive for ascarids, parasitic roundworms. It is likely that this individual is infected with *Ascaris lumbricoide*. Prevalent in areas of poor sanitation, *Ascaris* infections affect as many as a quarter of the world's population and can cause disease in their domesticated animals. According to Crompton (1999), roughly 1.5 billion individuals are infected with these roundworms. *Ascaris* eggs are passed in the fecal material of infected individuals. Once ingested, the eggs hatch and the larvae burrow through the intestines into the blood stream. Utilizing the blood stream, they enter the lungs of the host from where they access the esophagus (Schmidt and Robert, 2000). Their presence stimulates the host to cough and reflexively swallow the larvae, which mature in the intestine

and anchor themselves to the intestinal wall (Bogitsh et al., 2005). The eggs appear in the stool 60-70 days after infection. Many cases are asymptomatic; however, some patients suffer pulmonary symptoms, neurological disorders and pneumonitis when the larvae are migrating. In its final stages patients can suffer from gastrointestinal discomfort, diarrhea, vomiting, fever and colic (Schmidt and Robert, 2000).

4.10 Conclusions

Six of 100 chimpanzee samples tested positive for parasites, whereas three of 45 humans were positive. It is impossible to determine the directionality of disease. However, identifications of these parasite species provide insight into their lifecycles and suggest modes of transition that may include zoonotic transmission. Improvements in human access to potable water and sanitary toileting facilities (see Chapter 5) can act to reduce the possibility of cross species transmission and aid in the overall health of both humans and chimpanzees.

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Chapter Five

Ethnoprimateology

5.1 Sympatry Between Chimpanzees and Humans in Southeastern Senegal

In Chapter 3 the Dhiajenké, Bassari and Malinke people were introduced. Each of these groups employs different religious systems, has different cultural affiliations and utilizes different languages (Clavette, 2003) (Table 5.1). However, they all come in contact⁶ with chimpanzees while farming and collecting fruit and firewood from the chimpanzees' home range (Clavette, 2003). In addition, similar social constraints for each human group provide a level of protection for the chimpanzees. As previously discussed, the hunting and consumption of free-ranging NHPs is a major threat to chimpanzee populations across Africa. However, in these three cultures the hunting and consumption of chimpanzee meat is considered inappropriate, profane, immoral and, in some cases, taboo.

*Table 5.1 Human Impact Within the Fongoli Chimpanzee Home Range**

People	Village	Religion	Language
Bassari	Petit Oubadji	Animism	Bassari (similar to Bedik)
Malinke	Fongoli	Muslim	Malinke (similar to Dhiajenke)
Dhiajenke	Djendji	Muslim	Dhiajenke
Bedik	Scattered	Animism/nominal Christian influence	Bedik

**adapted from Clavette, 2003*

5.2 Ethnographic Methodologies

In the sometimes-turbulent relationships between human and nonhuman primates it is clear that the possibility of disease transmission leaps exponentially as the interests of humans and NHPs clash (Wolfe et al., 1998). However, in areas where these risks are not

⁶ For the purposes of this study, contact is defined as visual observation of one or more chimpanzees by a human residing in one of the three villages. Those individuals who had not entered the forest within the last year were excluded from the results. If they responded negatively, the interviewer moved to the next question. If they responded in a positive fashion they would be asked if they ever saw chimpanzees.

applicable to local NHP populations, the possibility of disease transmission and exposure is still likely to be high (Wallis and Lee, 1999). I argue that it is not enough for scientists to focus on primate populations that are facing clear and present physical and environmental danger, but that attention must also be paid also to those primates involved in stable relationships with humans.

Ethnographic field methods are critical to a successful ethnoprimateological approach (Loudon et al., in press; Sponsel, 1997). By considering human impact on NHP populations, anthropologists can gain information that will help elucidate byproducts of this multifaceted relationship. Combining non-invasive fecal sampling techniques with ethnographic field methods, I was able to gain a greater understanding of the potential impact of humans on chimpanzees interactions in southeastern Senegal.

As discussed in previous chapters, chimpanzees at Fongoli come in close contact with the people living within their home range. Although biological sampling can provide a window of insight into these animals' disease ecologies, interviews with humans living in the area provided a framework in which to present this information. Interviews provide a depth of understanding into this complicated system of interaction unobtainable through typical behavioral data collection techniques. Combining techniques also enabled a triangulation of information to independently verify results both biologically and ethnographically (Ervin, 2005).

To gain a clearer understanding of the interactions between humans and chimpanzees in southeastern Senegal I employed rapid assessment procedures discussed by Ervin (2005). Utilizing this methodology I was able to interview 32 men and 20 women of varying ages from the three villages in the area (Table 5.2). Ages were estimated by the researcher and

were recorded as an open range (e.g., 26-30 or 35+). The interview process was meant to elucidate the conditions of public health of the villages surrounding the chimpanzees' home range. Interviews were informal, with open-ended questions, and lasted about 20-35 minutes each. The incorporation of these interviews with biological data provides a better understanding of the possible risks of zoonotic disease transmission (Ervin, 2005). As the project developed, it became clear that it would be necessary to add and omit questions in order to maintain their relevance to the research. Original research questions are presented in both French and English in Appendix 5. Updated questions are presented in English in Appendix 6.

Table 5.2 Demographics of Informants

<i>Age</i>	0-18		19-25		26-35		36-45		46-70		Unknown		Total
Sex	F	M	F	M	F	M	F	M	F	M	F	M	
Fongoli	0	0	0	0	0	0	4	0	1	3	0	1	9
Djendji	0	0	1	1	1	6	3	3	2	3	4	7	31
Petit Oubadji	0	1	0	3	1	2	0	1	0	2	4	0	14

The health and survival of NHP populations is reliant on the understanding and cooperation of the people who live among them (Dolhinow, 2002). This insight contributes to our knowledge of biological and cultural diversity while being fundamental for developing conservation strategies (Shepard, 2002). In this assessment, interview questions addressed chimpanzee origins, human NHP interconnections, general public health issues focusing on parasitic disease transmission and village treatment of such ailments.

5.3 Interview Results: Human and Chimpanzee Interconnections

It is intriguing that humans in this area, regardless of affiliation, avoid chimpanzee meat while some readily consume other NHPs in the area (Table 5.3).

Table 5.3 Nonhuman Primates in Southeastern Senegal

Scientific Name	Common Name	Weight
<i>Pan troglodytes verus</i>	Chimpanzee	40-60 kg
<i>Papio hamadryas papio</i>	Guinea Baboon	17.6 kg
<i>Erythrocebus patas</i>	Patas	7-13 kg
<i>Chlorocebus aethiops</i>	Vervet	3.1-6.4 kg

All of the individuals interviewed at Petit Oubadji all reported eating patas monkeys, vervets and baboons, whereas less than a fourth of those interviewed at Fongoli and Djendji reported eating these animals (Table 5.4). This variation may be attributed to cultural constraints within this Islamic religion (Table 5.1).

Table 5.4 The Consumption of Patas, Vervets and Baboons Cross-Culturally

	Consumes NHP	Does Not Consume NHP	Undecided
Fongoli	2	6	1
Petit Oubadji	11	0	0
Djendji	4	23	3

Although some people readily discussed the hunting and consumption of baboons, patas, and vervet monkeys, all participants denied that they hunted or utilized chimpanzee meat. When asked why a person would eat monkeys but not chimpanzees a general consensus of relatedness to humans arose from my informants. Although some people simply said that chimpanzees and humans are more closely related than either is to monkeys, men commonly provided variations on the stories below.

Many years ago, god/chief forbade the people from fishing on Friday. Some people still did it and as a punishment the god/chief changed them into the primates. The [name of the group I was speaking with] became the chimpanzees, the [closest neighboring group to the interviewee] became the baboons, the [next closest group] became the vervet monkeys and the white people became the patas monkeys.

Many years ago, the Bedik boys were preparing for the circumcision rituals. As the day arrived four boys slipped into the forest to escape the knife. Because they were so ashamed that they did not become men, they decided to stay in the forest and slowly became animals. That is why chimpanzees avoid humans in the forest today, they are ashamed.

In light of the present research, the most interesting reoccurring theme throughout these stories is the connection of chimpanzees to human populations. Thus, as people internalize these stories and traditions, the preservation of endangered animals such as chimpanzees may be bolstered. Baboons, patas monkeys and vervets also play a role in the creation mythology of chimpanzees, and according to the first story, also share human origins. Although it is likely that these oral traditions have maintained a buffer between chimpanzees and humans, this pattern may be explained by alternative means.

In the Central African Republic, burgeoning human populations have been monitored closely regarding their bushmeat extraction practices. Remis (2006) found that when both large and small game is available, people prefer the small game animals for their ease of capture and portability. However, as human pressures reduced the amount of small game available, the extraction of larger animals such as elephants and gorillas dramatically increased (Remis, 2006).

Although it is too soon to say if this is the pattern developing in southeastern Senegal, it is important to note that informants reported a preference for patas monkeys over vervets, although patas weigh considerably more than vervets (Table 5.3). In addition, Clavette (2003) reports that people in this area preferred warthog meat (*Phacochoerus aethiopicus*) to

all other mammals. Warthogs can weigh up to 120kg, a full 60kg more than a male chimpanzee (Estes, 1991).

Taken into consideration, people's hunting preferences in the region suggest that social constraints manifested in oral traditions do provide some level of protection for chimpanzees and to a lesser extent, other primates in the area. In addition to bolstering conservation efforts, the avoidance of NHP meat may help protect humans from exposure to contaminated membranes, blood and muscle. The similarities of humans and other primates, especially the great apes, may place them at intensified risk of zoonotic disease transmission (Chapman et al., 2005). Thus, oral traditions and culturally imposed sanctions regarding the consumption of great apes may prevent exposure to infectious materials. However, it is likely that intensified extractive practices associated with escalating rural populations may place the Fongoli community at risk in the coming years. For example, previous generations of Bedik did not consume monkeys; this exploitation appears to have been a result of the diminishing supply of game in the region (D. Kante, personal communication).

5.4 Interview Results: Public Health

In an areas such as southeastern Senegal where waste disposal and potable water is considered a luxury, residents face exposure to a range of pathogens, bacteria, protozoa and parasites (Freeland, 1976). Such exposure comes from contact with other humans and their waste products, lack of sanitation, contaminated water sources and contact with domesticated and wild animals. Like any human community, however, members of these villages are not passive victims but are instead actively involved in preventative measures to halt or slow disease.

Sanitation

Sanitation is one of the most important steps to improving public health in developing countries (McKeown, 1998). This includes improvements in the sanitation of health care environments, food preparation and toiletry behaviors. Public health is focused nearly exclusively on human health; however improvements in the health and sanitation of human communities can have far-reaching effects on NHPs and their shared ecologies. For instance, human fecal material deposited in an unsanitary fashion can place chimpanzees at a greater risk of human parasitic transmission and infection (Wallis and Lee, 1999). For these reasons, conservation and public health initiatives need to consider culturally acceptable forms of waste management.

Within the three human communities I interviewed, there was differential access to sanitary toileting facilities⁷. Fongoli had the poorest toileting facilities. All three families excreted directly into the shrubland that marks the periphery of the village. Petit Oubadji consists of seven families who shared a communal toilet. Of the approximately 17 families living in Djendji, approximately four households (22.8%) did not own a toilet. It is important to note that even in areas where toilets were available, many men preferred to continue using the periphery of the camp.

The lack of sanitary toileting facilities in human settlements can result in a build up of fecal material contaminated with helminthes eggs, protozoan cysts, and bacteria (Freeland, 1976). Excessive contamination characterizing the periphery of human settlements increases the risk of interspecies transmission and reinfection (Freeland, 1976). Although chimpanzees do not often frequent the peripheral village areas heavily utilized as toileting facilities, the

⁷ In this case a sanitary toilet is any space that encloses potentially infected fecal materials.

behavior of infected humans may place the chimpanzees at risk by exposing them to potentially contaminated human fecal material.

Reduction of Disease Exposure Through Human Behavioral Adaptations

Disease and parasitic infections whose life cycles include shedding and infection through fecal material can be contracted through contaminated soils, carried in human bowels and expressed within the chimpanzees' home ranges. As discussed in Chapter 4, humans utilize portions of the chimpanzees' home range extensively for collection of *Saba*, firewood and the cultivation of crops (Pruetz and Knutsen, 2002; Clavette, 2003; Waller, 2005). In fact, of the 54 people I interviewed, only two of them reported not entering the 'bush' multiple times a week.

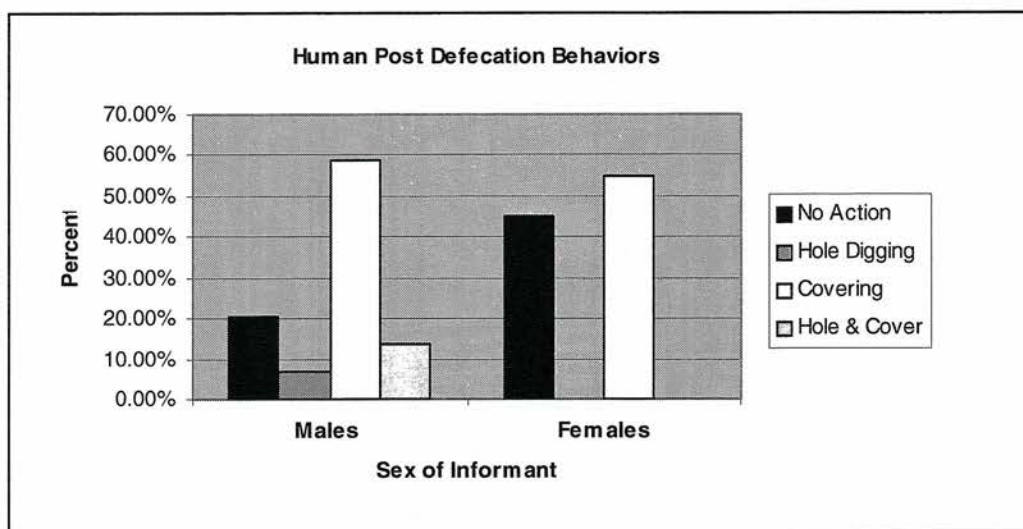
The majority of adults involved in this study frequented the forest, spent extensive periods of time away from home and inevitably defecate there on occasion. The sympatric nature of humans and NHPs here can lead to the exposure of chimpanzees to the infected fecal material of humans. However, due to the immense space utilized by the chimpanzees, the actual amounts of human waste chimpanzees are exposed to is unknown.

Clearly, there are few realistic alternatives for humans to defecation while farming or collecting *Saba* fruits. However, the behaviors associated with this action can increase the risk of disease transmission to humans and other animals. For example, digging a hole or simply covering up the waste with ground brush or stones reduces the exposure of individuals to infected material. This may also prevent domesticated and free ranging animals from treading in potentially infectious material and spreading it further.

As part of the interview process, people were asked to discuss what they did (if anything) after defecating in the bush. Answers were coded into four separate categories.

These included 1) no action taken to cover feces or prepare a hole, 2) hole digging discussed, 3) coverage of fecal material discussed, and 4) both hole digging and coverage discussed. All of the 29 men interviewed answered the question; compared to 20 of the 25 women. Village responses have been combined and presented in Figure 5.1.

Figure 5.1 Post Defecation Disease Controlling Behaviors



Compared to men, women were more likely to report doing nothing with their fecal material. Women reported either doing nothing with their waste, or covering it with brush and leaves. However both men and women were more likely to report taking action after defecating then simply leaving it exposed to the elements. When women were asked why they would cover it instead of simply leaving, a typical responses was “it’s dirty and people shouldn’t see it,” or “other people might become disgusted.” Men provided similar responses but also discussed concerns with stepping in other peoples waste while walking through the bush.

Two of the men described digging holes before defecating. One of these men is currently employed as a field assistant by Dr. Pruetz and has been briefed on field sanitation procedures following Collins (2003). His response may indicate an adherence to these expectations. However, other participants described hole digging as a somewhat futile and frustrating behavior that they saved for water collection and field preparation. Because their focus was less on sanitation and more on aesthetics, it is not surprising that most people would choose to cover their waste instead of burying it.

Water as a Source of Zoonoses

Many waterborne pathogens of humans including *Entamoeba histolytica*, *Giardia* spp, *Entamoeba coli* can also infect nonhuman primates (Chapman et al., 2005). These pathogens are all dependent on host contact with infected water for infection and re-infection. Exposure and transmission of these diseases increase for primates who frequent water sources heavily utilized by humans (Chapman et al., 2005).

Poor sanitation is not the only concern in regards to zoonotic disease transmission. From the archaeological record, it is clear that rates of disease increase with increased human populations and a less mobile way of life, and this continues to hold true in modern populations (Larsen, 2003). More sedentary groups often have less sanitary conditions due to the increased number of individuals living within a certain area. Without functional methods of containing and removing waste products, the biotic build can overwhelm the ecosystem. In these reduced sanitary conditions chances of infection dramatically increase (Larson, 2003).

As more people utilize limited water sources for washing their clothes, bodies, and cooking utensils, the contamination of these sources increases. In many cultures people defecate directly into these sources in an attempt to quickly remove fecal material from their

living spaces (Roberts and Janovy, 2000). In addition, domesticated and free living animals are typically able to access this resource leading to further contamination. These behaviors are known to increase the likelihood of certain parasites to spread (Roberts and Janovy, 2000; Wolfe et al., 1998). The result is that the water becomes contaminated with a variety of parasites such as hookworm and schistosomiasis (Larson, 2003).

The Gambia River is the most substantial waterway available to inhabitants of the study area. It runs west-east and is found in association with the villages of Petit Oubadji and Djendji. An offshoot of the Gambia is the Fongoli stream, which runs northwest-southeast and is associated with the village of Fongoli. In addition to these water sources, small sources are available throughout the forest during the wet season, and Djendji had a well. These water sources are relied on by humans for bathing, cooking, washing clothes, and drinking (Figure 5.3).

Figure 5.2 Woman and Child Washing Dishes in the Fongoli River



In the dry season water becomes scarce for both humans and animals in these rural areas and results in a concentrated use of the few sources available (Carter et al., 2003). Water sources shared between humans and chimpanzees may play an important role in pathogen transmission and exchange (Chapman et al., 2005; Wolfe et al., 2005). In this area

the risk of shared contaminated water was determined through interviews and coliform testing.

Behavioral observations suggest that chimpanzees exploit some of the same water sources such as streams (e.g., Fongoli stream) as humans in all seasons. Reduced access to water seems to constrict the ranging patterns of the chimpanzees and may bring them in increased contact with human settlements due to their concentration around water sources. For instance, during the height of the dry season, chimpanzees will restrict their movements to approximately 1 km a day outwards from water sources (Pruetz, pers comm.). This is concerning for several reasons. First, this constriction may result in increased contact with human populations, their fomites and infected fecal material. Second, concentrated use of a water source by multiple animals increases the risk of water contamination and subsequent infection (Chapman et al., 2005). During this season, the chimpanzees have been observed digging their own holes in the riverbed to gain access to water (Pruetz, unpublished data).

Those interviewed suggested that humans and chimpanzees only use the same water sources when it runs clear; otherwise people stay away from it. When asked where the chimpanzees drink in the dry season our respondents suggested the Gambia River and smaller water holes scattered through their home range. However, the banks of the Gambia River are a patchwork of agricultural fields that may dissuade chimpanzee use. Over the course of a year's follows, researchers at this site only witnessed the chimpanzees drinking from the Gambia River three times (Pruetz, unpublished data).

Without prompting, many of my informants discussed their avoidance of contaminated water sources. Contaminated water was described as cloudy or "dirty" looking. The only informant who discussed microbes specifically was a man who had received

medical training from American missionaries. However, he believed that clear water or water that had been passed through a cloth was safe to drink. Women were more likely to discuss methods of producing potable water and echoed his sentiment of clean water as clear or filtered water. They explained that boiling was preferable but did not consider this critical before ingestion.

One of the many effects of parasitic loads on human and nonhuman animals is the increased rate of iron deficiency anemia (IDA). Millions of people across the world are debilitated by this disorder (Roberts and Janovy, 2000). Infected individuals have low energy levels and perpetually feel dizzy and nauseous. In many situations people do not have the option of prolonged convalescence until their condition improves; instead they continue working. Women of childbearing age are particularly at risk due to the immense levels of iron necessary during pregnancy. Although poor diet can perpetuate this deficiency, it is water that is heavily contaminated by parasites that is at the root cause of the anemia (Walker, 1986).

Exposure to parasites and incidence of IDA may have a significant impact on NHPs. It is likely that debilitated adult females, laden with parasites, and her offspring would be exposed to increased predatory pressure. Predators (including humans) tend to focus on the slowest member of the community. In populations of extremely endangered animals the loss of a reproductively mature female and her most recent offspring can be devastating to the health and stability of the population.

The lack of clean drinking water in these situations creates a cycle in which humans, domesticates and free ranging animals are all able to infect and re-infect each other. This is called a feedback system and is especially common in human interactions with domesticated

animals (Daszak et al., 2000). In areas where people depend heavily on their livestock, the interaction between species can result in increased disease transmission. In areas such as southeastern Senegal where scarcity of resources may also lead to a higher risk of disease transmission, the interaction of abiotic (e.g., climate) and biotic (e.g., parasites) conditions result in problems for conservation biologists, health practitioners and social scientists (Walker, 1986).

If humans and chimpanzees are both utilizing the same water sources, and these water sources are contaminated they could both be exposed to a range of waterborne, zoonotically transmittable diseases (Wolfe et al., 2005). Although it is difficult and prohibitively expensive to test for many of these diseases it is feasible to test for coliform bacteria. Coliform bacteria are indicator organisms of fecal contamination in water. The presence of coliform bacteria may indicate fecal contamination of water sources that could lead to infection in those who drink from them.

Table 5.5 Coliform Test Results

Date	Location	Result
5/26/2005	Sakoto	Positive
6/1/2005	Fongoli	Positive
7/26/2005	Djendji	Positive
7/30/2005	Fongoli	Positive

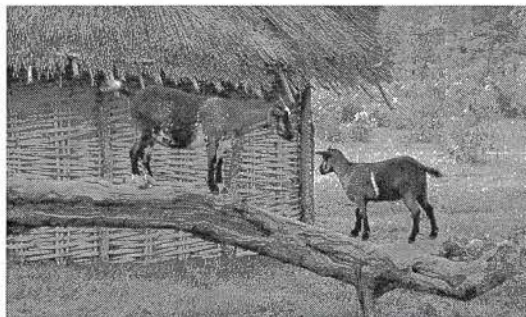
Between May and July 2005 researchers on the project utilized coliform testing kits from LaMotte. The Fongoli stream was tested at the end of the dry season when the greatest risk of contamination was thought to occur and again when it had been flowing heavily for a month and a half. All the samples collected, regardless of date, tested positive for coliform

(results in Table 5.5; Appendix 7). A positive results indicates that the water source has more than 20 coliform colonies per 100 mL of water.

Domesticated Animals and Zoonotic Disease Transmission

Each of the villages in which I worked was inundated with free ranging sheep, goats, cattle, chickens and dogs (Figure 5.3). These animals fill a range of needs from food and leather goods to protection and trade. Regardless of their role in society, these animals often wander throughout the village, on occasion entering a house whose owners failed to block the door adequately. For instance, I made the mistake of leaving my door unhinged while I bathed and returned to a roomful of chickens. After removing these animals from my hut, I realized that they had defecated on my backpack, bedding and the corn and millet stock.

*Figure 5.3 Domesticated Goats Free Ranging through Fongoli**



** Photo courtesy of Andrea Socha*

In addition to spreading disease with their own excrement, domesticated animals were observed to walk through areas used previously that day as a human toilet. Unlike humans who “watch their step” domesticated animals often walk through human excrement and spread contaminated matter throughout the human settlement (Armelagos, 1998). On several occasions it was suggested to me that dogs spread disease by walking through excrement, licking it off of their paws and then licking children. I also observed domestic ungulates

walking through the large piles of millet spread out to dry in each of these villages. Many people receive the bulk of their nutrition from millet; thus, the contamination of this stock could be detrimental to human health.

5.5 Medical Pluralism in Southeastern Senegal

I purposely avoided asking pointed questions regarding personal health because I am not a medical professional and did not want to be perceived as one. However, I did ask if people ever suffered from any gastrointestinal disorders. Everyone I interviewed mentioned some kind of gastrointestinal disorder from which they have suffered within the last month. These included stomachache, diarrhea and dysentery. Several of the people I interviewed from Petit Oubadji explained that, at the end of the dry season almost the entire village had been overtaken by dysentery. Thankfully, there were no reported deaths in association with this outbreak.

When asked how people within the community dealt with their ailments, I was surprised to hear that Western style medication was used as commonly as traditional medicine. Of the 53 people interviewed, 19 reported only using the hospital when they were sick, 17 reported relying on traditional medicines alone, and 17 reported using both the hospital and traditional medication depending on the severity of problem. When people discussed traditional medicine they suggested a range of roots and leaves that they employed to treat gastrointestinal ailments (Table 5.6). Combined with avoidance of chimpanzee meat, covering of fecal materials and attempts at water purification, the use of traditional and Western medicinal techniques indicates a proactive approach to disease avoidance and treatment on behalf of humans.

Table 5.6 Medicinal Plant Use for Stomach Pain and Helminthes

Plant	SCIENTIFIC NAME	Part of Plant	# Times Mentioned
Bato	?	Root	1
Canno	<i>Pterocarpus erinaceus</i>	Bark	10
Dekliekhe	<i>Ficus sp.</i>	Leaves and Bark	3
Diambakatanyo	<i>Cambretum</i>	Fruit	1
Dougouta	<i>Cordyla pinnata</i>	Bark	10
Filawo	?	Leaves	1
Jule Jule	?	Roots	1
Sene	?	Bark	1
Sindianjo	?	Root	4
Soucourango	?	Fruit	4
Tounsoume	?	Roots	2
Wourésése	?	Leaves	4
Wiracine	?	Leaves	1
Yiri Soulo	?	Unknown	1

5.6 Conclusion

In southeastern Senegal, chimpanzees play a significant role in human “place.” Chimpanzees’ reoccurring role as competitors for nutritional resources and as actors in the oral traditions of local humans have lead to their integration into the anthropogenically modified habitat in which they live (Fuentes and Wolfe, 2002; Pruetz and Knutsen, 2002). Indirect evidence such as chimpanzee feces and fresh chimpanzee nests as well as behavioral observation in areas utilized by humans confirms sharing of the same space. The interface between chimpanzees and humans has consequences for disease transmission and the health of both populations (Wallis and Lee, 1999). Thus, a stronger understanding of physical interactions between humans and chimpanzees, both through fecal material, contact with fomites (such as food wrappers, tissues and discarded food) and exposure to contaminated water sources, would provide an additional level of insight into conservation initiatives.

Human and NHP overlap can result in a multitude of outcomes. These multifaceted relationships can lead to the decimation of entire populations of the latter through loss of land and destruction of individuals due to the bushmeat trade, or protection through cultural traditions and taboos. This involvement can lead to serious impacts on NHP behavior, sociality and health and changes in primate population dynamics and can play a substantial role in primate socioecology and social dynamics. Thus, ignoring human behavior and cultural variation can lead researchers to miss important insight into the social behavior of their subjects.

The enormous variation found between different populations of non-human primates and the humans with whom they share their environment suggests that an approach that combines behavioral, biological, and ethnographic field methodologies is critical to understanding the full spectrum of variables. By determining potential modes of disease transmission, scientists are better able to pinpoint changes that would improve the living conditions and reduce disease risks to both species of primates.

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Chapter Six

Conclusions: An Applied Systems Approach to Public Health, Primatology and Anthropology

6.1 Introduction

This project helped create a pathway for establishing a simple baseline of chimpanzee health at Fongoli. In this matter, the project was a success. This study indicates that these chimpanzees are host to a number of parasitic infections that were previously unidentified. In addition, interviews with humans who utilize these chimpanzees' habitat have elucidated possible risks of zoonotic disease transmission between these two species, for example strongyloides and schistoma. These interviews also provided insight into the public health conditions experienced by local human populations. Combined, these data provide several directions of management and conservation that consider human access to chimpanzee habitat.

6.2 Disease Ecology and Public Health: New Avenues for Primate Conservation

The physical manifestation of disease is one of the few experiences shared by all organisms (Mcelroy and Townsend, 2004; Brown, 1998). Disease is ubiquitous among all species and can have a devastating effect at the individual, group, community, and population level. As evidenced by the rampant spread of Black Death (*Yersinia pestis*) throughout Europe and parts of Asia in the 14th century, disease has the power to level great civilizations (Davis pers. comm.). Although there are diseases whose frequencies increase in impoverished situations (e.g., tuberculosis) (Brown, 1998), no one, regardless of their economic status, is immune to the effects of disease. It is for these reasons that disease provides a strong example of the importance of an integrative systems approach for conservation and environmentalism. Including political, economic, social and environmental

factors into models of epidemiology can provide interdisciplinary teams with a holistic avenue of research and application. This may also result in more realistic solutions to compromised health within populations inaccessible to doctors and veterinarians working independently (Walker, 1986; Stuart and Strier, 1995; Dolhinow, 2002; Fuentes and Wolfe, 2002; Mcelroy and Townsend, 2004).

An integrative approach has been utilized in the public health sector and can provide a strong upon which to base NHP conservation plans. Combining anthropological approaches with public health initiatives can result in a more holistic approach to NHP conservation and human health. Among the various immediate needs during zoonotic outbreak, quick assessments by anthropologists could provide important behavioral and biological information. Understanding the mode of transmission can help with preventative measures. Biological anthropologists tracking NHPs would be able to report strange behaviors or developments in their animals. In some cases, an outbreak in free-ranging animal populations could forewarn health care professionals of an impending human outbreak.

6.3 The Role of Anthropologists in Conservation Initiatives

Permutations of human attitudes and relationships with their environments and, more specifically, with NHPs are staggering. It is for this reason that individuals trained in ethnographic methodologies need to address the impact of anthropogenic change on shared ecologies (Shepard, 2002). The combination of biological and cultural anthropology can provide critical information to conservation initiatives, which can result in practical applications that affect strategies of sympatry for humans and NHPs (Dolhinow, 2002).

The multifaceted relationship between humans and NHPs needs to be addressed previous to the initiation of primatological studies or creation of conservation strategies (Dolhinow, 2002; Fuentes and Wolfe, 2002). Attitudes of local people to NHPs ultimately effect how primates and their habitats are treated; thus, these kinds of data can provide insight into the potential for conservation policies before they are implemented (Strier, 2002). Anthropologists can also be instrumental in the dissemination of information to local communities and governments in a culturally sensitive manner (Shepard 2002).

6.4 Recommendations for Fongoli

In constructing conservation initiatives, there is a tendency for institutions to fit community needs and interests into predetermined conservation objectives, instead of using conservation to help fulfill community aspirations (Murphree, 2002). This directionality is a result of limitations on the time and resources of NGOs. To be successful, however, conservation projects must involve the advice and knowledge of local people and governments, which is best provided by cultural anthropologists (Dolhinow, 2002). Effective conservation programs are able to include a culturally relevant educational component that targets health clinics, local schools, and agricultural cooperatives may surround protected areas. Ultimately, they are able to improve health practices that are beneficial to all forest inhabitants, humans and NHPs (Wallis and Lee 1999).

In the past, primate conservation initiatives have focused heavily on acquiring land undisturbed by human behavior and creating wildlife reserves (Honey, 1999; Strier, 2007). In cases where there are sufficient financial resources for local enforcement and realistic alternatives for previous land inhabitants, reserves can protect primates and their habitats (Strier, 2007). However in developing countries such as Senegal where the Gross National

Income (GNI) per capita is \$825 or less (World Bank, 2005), and the population continues to grow (Sall, 2000), innovative approaches to primate conservation that include humans become a realistic alternative to reserves (Hutton and Leader-William, 2003).

Instead of excluding humans from models of chimpanzee conservation, I suggest creating a model that limits human migration and exploitation in this area but enables long-term residents continues inhabitation. This has been done, in part, through cooperation with the leader of the village of Djendji and authorities representing the region (i.e., Arrondissement of Bandafassi). The agreement limits the immigration of outsiders into forested areas for farming but does not limit the traditional farming practices of long-term residents of the area (J. Pruetz, personal communication). Although the chimpanzees are in far greater need of protection than human populations, I believe it would be erroneous and counterproductive to dismiss human needs completely for those of chimpanzees.

The current residents of Petit Oubadji, Fongoli and Djendji seem to pose minimal direct threats of disease transmission to the Fongoli community of chimpanzees. However, people from different ethnic backgrounds who are moving into this area may place undue stress on the ecosystem. As human populations continue to grow in the chimpanzees' home range, and the acquisition of *Saba* continues to provide a lucrative income to rural Senegalese, the pressures on this population of chimpanzees will increase (Knutsen, 2003; Waller, 2005). Research into the extraction of *Saba* indicates that the removal of this key resource will soon outpace its regeneration abilities (Pruetz and Knutsen, 2002; Knutsen, 2003).

In addition to resource extraction, immigration is also a threat to the Fongoli ecosystem. For instance, recent immigration into the area by the Puhlar herdsmen has

resulted in the decimation of land. While herding sheep through the chimpanzees home range, the Puhlar herdsman removed browse that surrounded the Djendji water hole (Pruetz, pers. comm.), a key water hole for chimpanzees, within a two-week span of time, and cut specific trees throughout the study area (J. Pruetz, personal communication).

Considering the minimal impact current residents have on the land at the Fongoli study site, and the clear environmental risks presented by more recent immigrants, I would recommend placing additional limits on aspects of immigration into this area. As part of limiting immigration, I would reduce the amount of *Saba* extracted from the chimpanzees' home range and sold to non-regional dealers. National parks such as Parc National du Niokolo-Koba have been successful in establishing protected chimpanzee habitats in part by excluding human development. Fongoli may provide an excellent test case for the establishment of a Senegalese community forest that works closely with current residents of the land. The key to this move is to maintain and potentially decrease current levels of anthropogenic disruption while actively preventing it from increasing.

In addition to providing community park status to Fongoli, I suggest improving the standards of health for humans in the area. I believe this would be best accomplished by providing accessible and affordable health care to its residents, improving health education initiatives, and creating better sanitation facilities. Currently, the nearest health care center is in Kedougou, 10km away. In the dry season this trip can take up to 35 minutes by car, although relatively few residents have access to such rapid transport. In the wet season, the roads are frequently washed out and the trip can take exponentially longer. Although most residents did not think the costs of health care were prohibitive, they often cited lack of transportation as a boundary from gaining these services. By establishing and supporting a

basic health care clinic accessible to the residents of Petit Oubadji, Fongoli and Djendji, infectious diseases may be addressed in a more timely matter and may help control cross-infection into the chimpanzee population.

This clinic would also be involved in health education programs for adults and children. These programs would address basic health concerns and preventative measures for the most commonly suffered diseases. In addition, they would be able to promote the importance of sanitary human waste disposal and encourage the digging of holes and the covering of fecal materials.

Increasing the accessibility to basic health care and health education is important long-term move to improving the health of residents of rural southeastern Senegal. However, establishing drop toilets and wells accessible to all members of the community may provide benefits within a relatively short period of time. Providing community members with access to sanitary toileting facilities and potable water would act as an effective preventative measure against some of the most common diseases facing rural populations.

While establishing a protected national park and providing health, health education and sanitary facilities, I would also promote the involvement and collaboration of Senegalese and Western scientists in this area. The expertise of these professionals would include doctors (both veterinary and medical), public health officials, primatologists, anthropologists and other similar specialists.

This study is meant to provide a preliminary baseline for professionals to monitor changes in the health of chimpanzees and humans. As the habituation of the chimpanzees continues to improve, year round monitoring of the community and specific individuals is possible and can provide further insight into the health dynamics of these two communities.

6.5 Conclusions

A systems approach to disease ecology represents a dynamic and complex model of ecosystem health. To be successful, it must include the expertise of both biological and social scientists. Often social scientists are considered extraneous to such projects and are the first members deleted in tight budgets. Nonetheless, the role of anthropologists in studies of disease ecology is immensely important. In many ways they are able to work as ambassadors and cultural translators. In critical situations, such as outbreaks of Ebola, SARS, and avian flu, rapid assessment techniques completed by anthropologists familiar with the culture could help produce important insight into risks of infection and disease spread.

For the systems style of integrative science to work, students in these fields must be exposed to a cross-disciplinary approach to these issues. Anthropology has led the way for this style of training with subfields such as applied anthropology, ecological anthropology, medical anthropology and primatology. Increasingly, medical schools are taking an ecological approach to medicine, with universities such as Harvard and Yale promoting environmental training opportunities to their medical students. Other schools are increasingly including medical anthropology into their required curriculum.

It is unfortunate that, at a time when the emphasis in national scientific funding is focused on integrative approaches to broad-spectrum issues, that anthropology departments across the nation are becoming more segregated and specialized. Together, biological and cultural anthropology provide a critical service to conservation teams focusing generally on forest preservation and nonhuman primates.

The future of conservation efforts and human health is reliant on biological and social scientists understanding their discipline's role in the environment. By restructuring the ways

in which conservation biologists, biomedical scientists, social scientists and NGOs interact with each other conservation initiatives can be more effective (Mcelroy and Townsend, 2004). With time, patience and some creativity, collaborative efforts can produce results unobtainable alone.

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Appendix One

Fecal Collection and Processing

Collection of Fecal Samples for Gastrointestinal Parasite Analysis

- 1.) Prepare collection tubes containing 10% buffered formalin (preferred for helminths) or poly-vinyl alcohol (preferred for protozoa).
- 2.) Before collecting feces, examine macroscopically for, and note, consistency, presence of blood, mucus, tapeworm proglottids, and adult or larval nematodes.
- 3.) With gloved hands, use a wooden applicator or spatula to scoop ~ 2 g sample from within the fecal mass into the collection tube (by taking the sample from within the fecal mass, you reduce risks of contamination by free-living nematodes in the immediate environment).
- 4.) Close tube, and label with identification #, date, time, initials of collector, ape species, location (GPS coordinates), and age/sex/identity of individual sampled if possible.
- 5.) Shake the tubes vigorously to maximize contact between sample and storage solution.

Fecal Flotation

- 1) Add 1 g feces to centrifuge tube.
- 2) Fill centrifuge tube 2/3 with distilled water and homogenize fecal pellet using a wooden applicator.
- 3) Centrifuge samples at 1,800 RPM for 10 min.
- 4) Pour off supernatant.
- 5) Re-suspend fecal material in NaNO₃ solution.
- 6) Fill tube to meniscus with NaNO₃ solution, and place microscope cover slip on lip of tube.
- 7) Centrifuge samples at 1,800 RPM for 10 min.
- 8) Remove cover slip from centrifuge tube and place on a slide labeled with the sample number.

- 9) Scan slide using the 10X objective of a compound microscope and identify and count all parasite eggs, larvae, and cysts. Use the 40X objective for measurement and confirmation of identifications.
- 10) Scan slide under 40X objective to confirm presence/absence of protozoan cysts (add a drop of iodine to facilitate identifications).
- 11) Measure the length and width of individual eggs, cysts, and larvae using a calibrated ocular micrometer.
- 12) Photograph representatives

Fecal Sedimentation

- 1) Suspend fecal pellet in 40 mL sedimentation solution (dilute soapy water) in a 50 mL beaker.
- 2) Filter suspension through cheesecloth held over lip of beaker, into a 50 mL centrifuge tube. Rinse cheesecloth with sedimentation solution and re-filter through cheesecloth. Dispose of cheesecloth and remaining fecal pellet.
- 3) Allow filtered suspension to settle until sediment is apparent (5 min).
- 4) Remove supernatant by pipette and rinse remaining material into disposable beaker with sedimentation solution.
- 5) Repeated until supernatant is clear.
- 6) Transfer 5 drops of sediment to a slide labeled with the sample number and cover with two cover slips placed side by side.
- 7) Scan slide under 10X objective and identify and count all parasite eggs, larvae and cysts. Use the 40X objective for measurement and confirmation of identifications.
- 8) Scan slide under 40X objective to confirm presence/absence of protozoan cysts (add a drop of iodine to facilitate identifications).
- 9) Measure the length and width of individual eggs, cysts, and larvae using a calibrated ocular micrometer.

Photograph representatives.

Appendix Two
Results Fongoli Chimpanzee Fecal Samples

SAMPLE	COLLECTED	BY	IDENTITY	LEAF SWALLOWING?	POSITIVES
F4	6/6/2005	JP	Unknown	N	N
F5	6/6/2005	MH	Unknown	N	N
F6	6/6/2005	MH	Unknown	N	N
F7	6/3/2005	JP	Unknown, JV?	N	N
F8	5/30/2005	JP	Unknown, JV?	N	N
F9	6/4/2005	?	Unknown	N	N
F10	5/29/2005	MH	Unknown	Y	N
F11	6/3/2005	JP	Bandit (AM)	N	N
F12	6/4/2005	JP	Unknown	N	N
F13	6/4/2005	JP	Unknown	N	N
F14	6/4/2005	JP	UK, JV?	N	N
F15	6/4/2005	JP	Unknown	N	N
F17	6/4/2005	?	Unknown	N	N
F20	6/13/2005	JP	Unknown	N	N
F21	6/14/2005	AS	Unknown	N	N
F22	6/22/2005	?	Unknown	N	N
F23	6/11/2005	JP	Unknown	N	N
F24	6/11/2005	JP	Unknown	N	N
F25	6/15/2005	AS	Unknown	N	N
F26	6/15/2005	AS	Unknown	N	N
F28	6/15/2005	AS	Unknown	N	N
F29	6/15/2005	JP	Unknown	N	N
F30	6/15/2005	AS	Unknown	N	N
F31	6/11/2005	JP	Diouf (AM)	N	N
F32	6/11/2005	JP	KL (AM)	N	N
F33	6/11/2005	JP	Unknown	N	N
F34	6/11/2005	JP	Unknown	N	N
F39	6/17/2005	JP	Unknown	N	N
F40	6/17/2005	AS	Unknown	N	N
F41	6/16/2005	JP	KL (AM)	N	N
F42	6/16/2005	JP	Yopokon (AM)	N	N
F43	6/16/2005	AS	Unknown	N	N
F44	6/16/2005	AS	Unknown	N	N
F45	6/16/2005	AS	Unknown	N	N
F46	6/16/2005	JP	Unknown	N	N
F47	6/16/2005	JP	Unknown	N	N
F48	6/16/2005	JP	Unknown	N	N
F49	6/16/2005	JP	Nyegi (SAM)	N	N
F50	6/16/2005	JP	Unknown	N	N
F52	6/16/2005	JP	Unknown	N	N
F53	6/17/2005	JP	Unknown	N	N
F54	6/17/2005	JP	Unknown	N	N
F55	6/16/2005	JP	Unknown	N	N

SAMPLE	COLLECTED	BY	IDENTITY	LEAF SWALLOWING?	POSITIVES
F57	6/15/2005	JP	Mamadou (AM)	N	N
F58	6/17/2005	JP	Unknown	N	N
F61	6/15/2005	JP	KL (AM)	Y	N
F62	6/15/2005	JP	Tumbo (SAF)	N	N
F63	6/15/2005	JP	Nyegi (SAM)	N	N
F64	6/17/2005	AS	Unknown	N	N
F65	6/16/2005	JP	Unknown	N	N
F67	6/21/2005	JP	Unknown, Adult?	N	N
F68	6/18/2005	JP	Unknown	N	N
F69	6/22/2005	JP	Unknown	N	N
F70	6/22/2005	MH	Unknown	N	N
F71	6/22/2005	MH	Unknown	N	N
F72	6/10/2005	JP	Mamadou	N	N
F73	6/10/2005	MH	Male [KL or MM]	N	N
F74	6/22/2005	JP	Unknown	N	N
F75	6/22/2005	MH	Diouf (AM)	N	N
F76	6/22/2005	JP	Unknown	N	N
F77	6/22/2005	MH	Unknown	N	N
F78	6/21/2005	JP	Unknown	N	N
F79	?	?	Unknown	N	N
F80	6/22/2005	MH	Unknown	N	N
F81	6/22/2005	?	Unknown	N	Positive
F88	6/4/2005	JP	Unknown	N	N
F90	6/7/2005	JP	Mamadou	N	N
F91	6/22/2005	JP	Unknown	N	N
F92	6.21/2005	JP	Mamadou	N	N
F93	6/7/2005	JP	Unknown	N	N
F94	7/12/2005	JP	Unknown	N	N
F95	8/4/2005	JP	Male JV	N	N
F96	7/13/2005	JP	Bilbo (AM)	N	N
F97	7/21/2005	JP	Unknown	N	N
F98	8/4/2005	JP	SAM	N	N
F99	7/10/2005	JP	Nyegi (SAM)	N	Positive
F100	8/5/2005	JP	Tia (SAF)	N	N
F101	8/9/2005	JP	Unknown	N	Positive
F102	8/3/2005	JP	Nyegi (SAM)	N	N
F103	8/6/2005	JP	Tumbo (SAM)	N	N
F104	8/3/2005	JP	Tumbo (SAM)	N	N
F105	7/28/2005	JP	Tumbo (SAM)	N	N
F106	8/6/2005	JP	Unknown	N	Positive
F107	7/27/2005	JP	Unknown	N	N
F108	7/23/2005	JP	Unknown	N	Positive
F109	7/21/2005	JP	Bilbo	Y	N
F110	7/30/2005	JP	Unknown	N	N
F111	8/5/2005	JP	Tia	N	N

SAMPLE	COLLECTED	BY	IDENTITY	LEAF SWALLOWING?	POSITIVES
F112	7/12/2005	JP	Unknown	N	N
F113	7/19/2005	JP	Unknown	N	N
F114	8/9/2005	JP	Nyegi (SAM)	Y	N
F115	7/10/2005	AS	Unknown	N	N
F116	8/5/2005	AS	Unknown	Y	N
F117	7/10/2005	AS	Unknown	N	Positive
F118	7/9/2005	AS	Unknown	N	N
F119	7/11/2005	AS	Unknown	N	N
F120	8/5/2005	AS	Unknown	N	N
F121	8/5/2005	AS	Unknown	N	N

Note: Missing samples are an error in numbering during collection. No samples were excluded.

Age and Sex Classes

AM – Adult Male

AF – Adult Female

SAM – Subadult Male

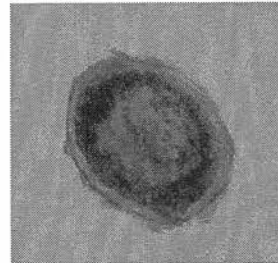
SAF – Subadult Female

Appendix Three

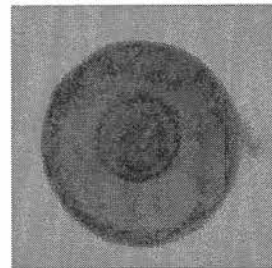
Pictures of Parasites

Sample F101

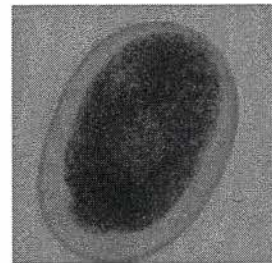
Possible Species: *Hymenolepis nana*

Sample F106, PO3

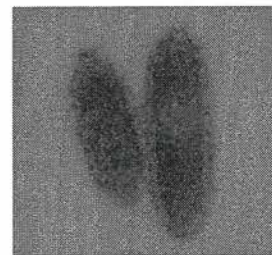
Possible Species: *Schistosoma haematobium*
Schistosoma mansoni

Samples F117, F108, DJ19

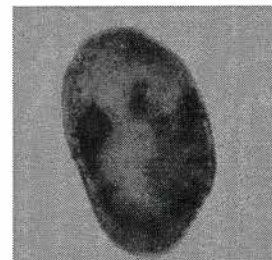
Possible Species: *Strongyloides fülleborni*
Strongyloides stercoralis

Sample F81

Possible Species: *Capillaria hepatica*
Capillaria aerophila

Sample F106

Possible Species: *Ascaris lumbricoides*



Appendix Four
Parasites of *Pan troglodytes*

Species	Resource
Phylum Nematoda	
<i>Capillaria</i> sp.	3
<i>Capillaria hepatica</i> *	6,10
Hook Worm	1,2
<i>Necator americanus</i>	
<i>Oesophagostomum</i> sp	1,3,8
<i>Oesophagostomum stephanostomum</i>	4,11
<i>Physaloptera</i> sp.	1
<i>Probstmayria</i> sp.	11
<i>Probstmayria gombensis</i>	1
<i>Strongyloides</i> sp.	3,6,8
<i>Strongyloides fuelleborni</i> *	1,4,6,11
<i>Strongyloides stercoralis</i> *	10
<i>Trichuris</i> sp.	1,3,11
<i>Trichuris trichura</i>	4
Phylum Platyhelminths	
<i>Cestoda</i>	6
<i>Dicrocoella</i> sp.	3
<i>Hymenolepis nana</i> *	6
<i>Schistosoma haematobium</i> *	9
<i>Schistosoma mansoni</i> *	1,6
Trophozoites	
<i>Troglodytella</i> sp.	3
<i>Troglodytella abrassarti</i>	8
Phylum Apicomplexa	
<i>Plasmodium reichenowi</i>	2
Phylum Ciliophora	
<i>Entodiniomorph ciliates</i>	5
Phylum Sarcomastigophora	
<i>Trichomonads</i>	7
Unknown Phylum	
<i>Oxyurid</i>	3

References from Chapter 4: (1) Murray et al., 2000 (2) Hughes and Verra, 1998 (3) Hasegawa et al., 1983 (4) Huffman et al., 1997 (5) Landsoud-Soukata, 1995 (6) McGrew et al., 1989 (7) Lilly et al., 2002 (8) Muehlenbein, 2006 (9) DePaoli, 1965 (10) Myers and Kuntz, 1972 (11) Kriefs, 2005

Appendix Five

Proposed Interview Questions

English

- 1.) Do you ever see chimpanzees?
- 2.) Where do you see them?
- 3.) Have the chimpanzees always been here?
- 4.) Where do the chimpanzees drink?
- 5.) Where do villagers defecate?
- 6.) Do you ever see chimpanzee feces?
- 7.) What do the chimpanzees eat?
- 8.) Do your people or people in the villages of [list other villages – eg. Petit Oubadji, Djendi, Fongoli, Ngare] ever eat monkeys?
- 9.) Do the [domestic animals] ever graze where the chimpanzees live?
- 10.) General question in regard to health. Stomach pains?

French

- 1.) Faites-vous voient jamais des chimpanzés?
- 2.) Là où vous voyez ils?
- 3.) Ayez chimpanzés toujours étés ici?
- 4.) Là où faites boisson de chimpanzés?
- 5.) Là où les villageois défèquent?
- 6.) Faites-vous voient jamais résidus de chimpanzé?
- 7.) Ce qui font les chimpanzés mangent?
- 8.) Faites vos personnes ou les gens dans les villages de [énumérez d'autres villages - par exemple. Petit Oubadji, Djendi, Fongoli, Ngare] mangent jamais des singes?
- 9.) Faites [les animaux domestiques] jamais frôlez où les chimpanzés de phase?
- 10.) Question générale en vue de santé. Douleurs d'estomac?

Appendix 6
Updated Interview Question

- 1.) Do you go to the bush?
 - a. If so do you see chimpanzees?
- 2.) [If yes to 1a] Where do you see the chimpanzees?
- 3.) Where do the chimpanzees come from originally?
- 4.) Where do the chimpanzees drink?
 - a. Do chimpanzees and humans drink at the same places?
- 5.) While in the village where do people go to the bathroom?
 - a. How many families have a toilet in this village?
- 6.) What do people do after they defecate in the bush?
- 7.) What do chimps eat?
- 8.) Do people eat monkeys? Do they eat chimpanzees?
 - a. If they eat monkeys but not chimpanzees, why?
- 9.) Do people have gastrointestinal problem? [If so] what are some examples?
- 10.) What do people do when they get sick?

Appendix Seven

Coliform Testing Procedures

Coliform test kits were part of LaMotte low cost water monitoring kit. They were comprised of a 15ml test tube with a 10 mL line and coliform testing tablet.

Water is collected in a sterile, wide mouthed jar or container (approximately 1 liter) that has a cap. If possible, boil the sample container and cap for several minutes to sterilize and avoid touching the inside of the container or cap with your hands. The container should be filled completely with your water sample and capped. Test each sample as soon as possible or within one hour of collection.

Testing Procedures

- 1.) Pour the water sample into the large test tube containing a tablet until it is filled to the 10 mL line.
- 2.) Replace the cap on the test tube.
- 3.) Stand the upright, with the tablet flat on the bottom of the tube.
- 4.) Incubate by storing the tube upright, at room temperature, out of direct sunlight, for 48 hours. Store the tubes where the temperature will be fairly constant and between 70° to 80°F (21° to 27° C). Do not disturb, handle, or shake tubes during the incubation period.
- 5.) Compare the appearance of the tube to the picture on the Coliform color chart (enclosed in kit). Record the result as positive or negative.
- 6.) Dispose of tubes by adding 20 drops of chlorine bleach and recapping immediately. After letting tube stand upright for four hours, dispose of closed tube in the trash.